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CONTRACTS FOR A GRANITE SEA WALL and filled pier at Boston Harbor will soon be let by the Board of Harbor and Land Commissioners of the State of Massachusetts. The pier will be located at South Boston Flats and will consist of a granite sea wall 3,000 ft. long, supported on pile foundations, and filled behind with about 300,000 cu. yds. of solid filling to form the wharf or pier. Docks are to be excavated at the sides of the pier to a depth of 30 ft. below mean low water and the pier is to be constructed so that a depth of from 35 to 40 ft. may be excavated when required. Contracts will require the work to be completed by Jan. 1, 1899, and proposals for construction are now being asked, as noted in our advertising columns.

THE RANGE OF TIDES in the Bay of Fundy is from 50 to 60 ft., but the level of the tide is rarely more than 22 ft. above sea level, the maximum having been 29 ft. The tidal wave in receding, however, carries out about the same depth of water below the mean sea level. The record of tidal range for 1894 is as follows, the figures being for the combined rise and fall:

	Spring tides. ft.	Neap tides. ft.
Digby Neck, N. S.....	22	18
St. John, N. B.....	27	23
Moncton, N. B	46	36
Noel River, Cobequid Bay, N. B.....	53	31

THE BROOKLYN DRY DOCK is again figuring in the newspapers, this time on account of a suit brought by the Government against the first contractor, John Gillies, of Brooklyn, N. Y., to secure damages for failure to complete his contract. It is stated in the claim that in 1892 Mr. Gillies took the contract to build the timber dry dock at the Brooklyn Navy Yard for $412,000, with the stipulation that the work was to be completed in 27 months. Subsequently the time was extended five months and the price increased to $462,619. The contractor started the work but, it is alleged, was slow and finally the contract was taken from him after he had received $163,033, and awarded to T. & A. Walsh, who completed the work for $370,000. Now the Government is suing the first contractor for $72,414, the difference between the amount paid altogether and the amount for which the contractor agreed to do the work.

THE LACHINE POWER PLANT, owned by the Lachine Rapids Hydraulic & Land Co., Montreal, Ont., was formally opened in the presence of some 2,700 invited guests and many others from Montreal and near-by places, on the afternoon of Sept. 27. The plant, described fully in Engineering News, Feb. 18, 1897, includes an extensive dam and canal at the lower end of one of the channels in the St. Lawrence River, formed by the Isle au Héron, a large power station fully 1,000 ft. long built upon the dam and eventually 12 three-phase generators geared to 72 Stilwell-Bierce & Smith-Vaile vertical shaft turbines, each 54 in. in diameter, giving 200 HP. with a 11 ft. head when running at 83 revs. per min. Each of the 12 dynamos will require 6 turbines. The generators are 760 K-W. machine wound for 4,400 volts and a periodicity of 60 cycles at a speed of 175 per minute, 12 40 K-W. 150 volt. direct current exciters will be required to furnish current for the revolving field. A complete transmission system is included which will convey current to several substations located in Montreal.

THE LOWEST COST OF STEAM POWER yet recorded viz., $11.55 per year of 3,070 working hours, is reported by Dr. R. H. Thurston in "Science" of Oct. 1, as having been reached in the Warren Steam Cotton Mill, Providence, R. I. The engine, designed by Edwin Reynolds, of the E. P. Allis Co., Milwaukee, is cross-compound condensing, rated at 1,950 HP.; cylinders 32 and 68 ins. by 5 ft. stroke, making 74 revolutions per minute. The steam pressure is 155 lbs. per sq. in. and the coal consumption is 1.35 lbs. per horse-power hour. Heine water tube boilers are used. Coal costs $2.26 per ton.

The following is a tabulated statement of the cost of power:

Fuel per horse-power per year of 3,070 hours....	$4.70
Labor	1.88
Supplies and repairs	.42
Total operating expenses	$7.00
Interest, at 5 per cent	2.05
Depreciation, at 5 per cent	2.05
Taxes	.41
Insurance	.04
Fixed charges	$4.55
Total cost of power per year	$11.55

The cost account includes the cost of steam used for all purposes, including banked fires, nights and Sundays, and that supplied the mill. The engine replaces a quadruple expansion engine which was destroyed by fire after seven years of service. It appears that the saving of fuel which may be made by a quadruple as compared with a compound engine is more than overbalanced by its higher first cost, when the engine is run only 10 hours a day and the cost of coal is as low as $2.26 per ton.

RAILWAY ACCIDENTS IN GREAT BRITAIN during the year 1896, according to the report of the British Board of Trade, just issued, resulted in the death of 1,008 persons, and the injury of 5,877 persons. Only eight persons were killed and 341 persons were injured by accidents to trains, rolling stock, permanent way, etc., the remainder of the fatalities and injuries being due to accidents from other causes, including accidents from want of care and misconduct on the part of the persons injured. Besides these accidents resulting from the movement of trains, 85 persons were killed and 11,092 persons were injured by accidents which occurred on the premises of railway companies, but which were not connected with the movement of trains. These very large figures of injuries are due in a considerable measure to the insignificant accidents which are reported; all injuries to passengers, however slight, being reported, and also all injuries to employees, which are serious enough to prevent the employee injured from working at his usual employment for five hours on any one of the three working days next after the occurrence of the accident. This condition needs to be kept in mind in making any comparisons between the figures of injuries in English and American railway accidents. This report brings out very strongly the small proportion of the total deaths and injuries from railway accidents in England which resulted from accidents to trains, and also the great extent to which carelessness and disobedience are responsible for railway accidents instead of mechanical defects. This feature was discussed at some length in our issue of Aug. 12, 1897.

THE MOST SERIOUS RAILWAY ACCIDENT of the week occurred on a narrow gage line of the Denver & Rio Grande R. R., near Cotopaxi, Colo., Oct. 3. The accident was caused by the breaking of a journal on the rear truck of a coach and resulted in the derailing of four cars, the injury of 13 persons and the death of 2. Had the train been running at regular speed, the casualties would have been great, for the train was crowded.

AN EXPLOSION OF ACETYLENE GAS is reported to have occurred in Rochester, N. Y., Oct. 4, resulting in the injury of two persons, and the probable death of a third. It appears that the three men were experimenting with a new form of valve to be placed on a galvanized tank about 2½ ft. in diameter, which was filled with acetylene gas. A gas jet about 3 ft. above the tank is supposed to have ignited the explosive gas with the results above mentioned.

THE LARGE CABLE POWER PLANT, owned by the Capital Traction Co., Washington, D. C., containing all the machinery for operating some 15 miles of track was completely demolished by fire on Sept. 30. The accident resulted in a shut-down of the car service on the principal streets of the city, and while horses and mules have been impressed to afford a temporary service it will be several months before rapid transit can be resumed. The building was 241 by 185 ft. and 6 stories high, the whole lower floor being occupied by the railway company as engine and boiler rooms, repair shop, offices, etc. The remainder of the building was occupied by an assortment of small industries, all using power supplied from the lower floor. The total loss amounts to about $1,000,000, $400,000 of which falls upon the railway company. The fire is supposed to have been caused by spontaneous combustion of material in a printing office on the third floor. In considering the question of rebuilding various systems of propulsion are being examined by the directors, but from present indications the cable conduit will probably be used as a conduit for electric conductors on a system much the same as that which has given such satisfaction both in Washington and New York. As an expedient, the Walker Co., Cleveland, O., has offered to install inside of ten days two electric motors capable of driving the cables until the conduit system can be completed.

REPORTS OF A DISATSTROUS FLOOD have been received from China. It is stated that 60 villages within 12 miles of Pekin, containing about 80,000 persons have been completely destroyed and that between 15,000 and 20,000 of this number perished. The report further states that the unusual rains which caused the flood began July 23 and continued almost constantly until Aug. 15.

WATER-WORKS PUMPING PLANTS as electric light stations are suggested by Mr. McGann, Commissioner of Public Works, of Chicago, who proposes to utilize the boiler batteries of the pumping plants to supply steam for the electric light plants at night, when there is less demand for water. In some cases the electric light stations are close to the pumping stations, and can be connected by steam pipes, but where this is not practicable, it is proposed to remove the electric light engines and dynamos to the pumping stations.

THE NEW YORK RAPID TRANSIT RY. PLANS have been approved by the Park Board, which removes another obstacle in the path of this enterprise. The attitude of the Park Board on refusing its approval some weeks ago, was commented on in our issue of Sept. 2. It is noticeable that its distinct change of base follows close upon a vigorous arraignment of that body for its obstruction to the Rapid Transit scheme, which forms part of the platform adopted by one of the city nominating conventions.

THE CARNEGIE STEEL CO. is making still further preparations for increasing its capacity for production. An entire new plant of open-hearth furnaces is being erected at Homestead. The company has purchased a five-sixth interest in the Norrie group of ore mines on the Gogebic range, Lake Superior, and a fleet of new vessels is to be built to carry this ore from Ashland, Wis., to the new railroad docks at Conneaut, Pa., on Lake Erie. The boats will probably be 450 ft. long and 21 ft. draft, with a carrying capacity of 6,000 tons of ore. The capacity of the Norrie mines is about 1,000,000 tons of ore per year.

WORK ON THE GEOLOGICAL AND ECONOMIC SURvey of West Virginia has been begun by effecting a formal organization of the commission authorized by the last legislature, as noted in our issue of June 24, 1897, and composed of Governor G. W. Atkinson; State Treasurer, M. A. Kendall; Dr. J. H. Raymond, President of the State University; J. H. Stewart, Director of the State Agricultural Experiment Station, and T. C. Atkinson, President of the State Board of Agriculture. The members of the commission are all members by virtue of their office. The organization of the commission was effected by electing Governor G. W. Atkinson, president; M. A. Kendall, treasurer, and T. C. Atkinson, secretary. The commission has appointed the following executive officers: Superintendent, Dr. I. C. White; 1st Assistant Geologist and Curator of the Collections, Prof. S. B. Brown; Superintendent of Biological Division, J. H. Stewart; Executive Officer, Dr. J. H. Raymond. It has also ordered Professor Brown, who holds the chair of geology at the state university, to collect and prepare for publication a synopsis of all the works bearing on the geology and biology of West Virginia. With this accomplished there will be a certain amount of information to start with, and then the geological survey of the state can be carried on as funds will permit. It is thought the work will take about ten years. The legislature appropriated $6,000, and if succeeding legislatures continue to appropriate the survey will proceed until completed. It is proposed to co-operate with the United States' engineers now in the state.

THE PRODUCTION OF KEROSENE OIL IN JAPAN bids fair to become very extensive as soon as the present inadequate methods of development and working are improved. United States Consul-General McIver, writing from Kenagawa, Japan, says:

The oil districts of Japan extend from Hokkaido to Akita on the north, traverse the provinces of Echigo and Shinano, and reach the Totomi province. In Amagase-machi, Mishima district; Nitsumachi, Kambara district; Miyagawamachi, Kariha district; and Urase, Koshi district, in Echigo province, there are a number of companies which have boring machinery used for their work. The number of machines now in course of fitting up by the various companies in Tosan district is 56. Besides, 28 machines will have to be fixed within the year, making the total 84. Hitherto the work has not been earnestly undertaken on account of the easy access to the foreign oil, and the wells have been sunk in an unscientific manner about 600 ft., but since 1890 American boring machinery and its accessories have been introduced, and at present oil is taken out from the depth of 800 to 2,000 ft. The process of refining has also been greatly improved, so that Japanese oil is now practically the same in quality as foreign petroleum. The principal markets of the Echigo oil are the Hokkaido, Shinano and northern provinces in the mainland.

In 1894 the total production of Japanese petroleum was 658,260,000 gallons, which did not supply the demand. The Japanese people seem to be fully aware of the importance of developing the native production of petroleum, and it might be worth while for American manufacturers of oil-well working machinery to investigate the Japanese oil fields as a possible market for their products.

THE NEW VICTORIA HIGHWAY BRIDGE, BRISBANE, AUSTRALIA.

(With full-page plate.)

We illustrate on our full-page plate and in the accompanying cut a number of views of the new six-span, highway bridge recently opened for traffic across the Brisbane River, in the city of Brisbane, Queensland, Australia. This structure replaced an old bridge on the same site, and was built under the direction of Mr. Alfred B. Brady, M. Inst. C. E., engineer for bridges to the Queensland Government. We are indebted to Mr. Brady for the photographs and information from which the following description was prepared.

It will be noticed from the various views that considerable effort was expended to beautify the bridge and its approaches, and a comparison is naturally suggested between this work of the English engineer and the very carefully studied American bridge illustrated on the opposite page of our inset sheet, although it would be manifestly unfair to carry such a comparison too far or to draw any sweeping conclusions from it. It is, perhaps, sufficient to note simply that in both bridges the designers attempted to please the eye as well as to build an efficient tool for transportation. To see how inexpensively a little study can accomplish pleasing results, the reader has only to glance at Figs. 2 and 3. In Fig. 2 is shown how some taste in using an ornamental bracing has turned what might have been a very ugly pier construction into something quite pleasing to the eye. In Fig. 3 is shown how a naturally ugly portal has been improved by building two very simple arches over the footways, and by emphasizing the division of the roadways by a masonry column surmounted by a cluster of lamps.

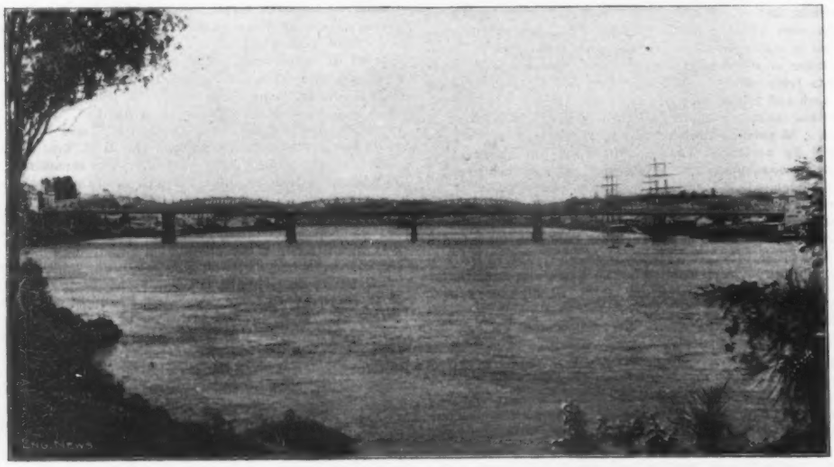

FIG. 1.—THE NEW VICTORIA BRIDGE ACROSS THE BRISBANE RIVER AT BRISBANE, AUSTRALIA.
Alfred B. Brady, M. Inst. C. E., Government Engineer for Bridges.

The Victoria bridge consists of six 170-ft. spans (Fig. 1), with three main longitudinal girders in each span, the whole carried upon five piers of three cylinders each. The girders are of the hog-backed, lattice type, 22 ft. deep at the center, and 10 ft. deep at the ends, and are constructed of steel. The cylinders of the piers are of cast-iron, and the abutments are of masonry backed with concrete. For about half the length of each span the girders are braced overhead with light lattice girders and diagonal bars to resist wind pressure. One end of each main girder is fixed on cast steel rocker bearings, but the opposite end rests on expansion rollers of cast steel, of an improved interlocking pattern. The bearings of the main girders on the abutments rest on massive granite bed-blocks.

The length of the bridge over all is 1,040 ft. 8 ins., the clear length between the faces of the abutments being 1,011 ft. 8 ins., while the width between the parapets of the footways is 73 ft. The height of the roadways above high water mark is 36½ ft. at the north end, and 25 ft. at the south end of the structure, the gradient on the roadway of the bridge being at the rate of 1 in 90. The bridge affords a clear headroom of 3 ft. more than existed under the superstructure of the old iron bridge. This extra height was deemed desirable for the reason that the old bridge had been overflowed and injured by a heavy flood which occurred in 1893. The total weight of iron-work and steel-work in the bridge, including superstructure and piers, amounts to 3,315 tons, the whole of which was manufactured in the Colony.

Every cylinder, three of which form a pier (Fig. 2), was sunk to a hard rock foundation, each pier in the direction of the stream having a width or base of 63 ft. The maximum depth any cylinder was sunk was 96 ft. 9 ins. below high water level. The diameter of the cylinders from the foundation level to the river bed is 10 ft., but at that level the diameter is reduced by a tapering cylinder to 8 ft., and again at high water mark the diameter is reduced 6 ft. by a strongly molded base casting on the cylinder. All of the cylinders are completely filled with Portland cement concrete and are finished with ornamental cast-iron caps, cornices and bases, in keeping with the architectural treatment of the stone abutments and arches. Wrought iron riveted bracing of great strength connects the cylinders, each pier having four elliptical panels and girder ties above high water mark. The cylinders are further braced with heavy cast-iron spandrels firmly bolted to them below high water level.

It is considered by the designer that the bridge gains considerably in beauty and finish by having massive and architecturally-treated masonry abutments and arches over the footways at each end (Fig. 3). The abutments are faced with O'Connelltown (near Brisbane) purple hardstone, rock-faced, and surmounted by heavy molded and bracketed cornices of brown freestone. The lamp pillars and piers to the archways are of Helidon freestone in alternating courses of brown and white. Surmounting each arch is an entablature treated in the Doric style.

There are two road or carriageways and two footways. The center girder divides the roadways, which are each of a clear width of 24 ft. Cantilevers springing from the outer girders carry the footways, each 9 ft. wide in the clear. The decking of the bridge is constructed of steel trough plates laid transversely from girder to girder. This decking has been covered with cement upon which a pavement of hardwood blocks (Fig. 4) has been laid on the latest and most approved system, forming the carriageways. It is intended that the downstream roadway shall be used by vehicles traveling from north to south, and the upstream roadway for traffic from South Brisbane to the city. The flooring of the footways consists of corrugated steel plates (Fig. 5), laid longitudinally, riveted to the cantilevers, covered ith coke concrete, and finished on the surface with Limmer rock asphalt 1 in. thick. The parapets of the footways are of wrought iron lattice-work with a molded hardwood handrail, and ornamental wrought iron brackets on the ends of the cantilevers.

The approach to the bridge on the south side has been increased in width from 66 ft. to 132 ft., and the levels on both north and south sides have been raised to accord with the level of the roadways on the new structure.

Provision has been made to carry water over the bridge by means of two riveted steel, 12-in. pipes, suspended close to the underside of the decking, on each side of the center girder. The tramways have been laid in each roadway alongside the center girder. The telegraph and telephone cables are carried over through a number of 2½-in. iron tubes laid beneath the asphalt of the footways, inspection boxes with covers flush with the surface of the footways being provided at suitable intervals. The unsightly overhead system of telegraph wires has been done away with by this construction.

The bridge and its approaches are lighted by gas, supplied to the lamps by service pipes from the companies' mains, half the supply being drawn from the city side, and half from the south side of the river. The lamps are carried on ornamental cast-iron standards on the stone lamp pillars, and at the intersections of the outer girders, and on each side of the archways on ornamental wrought iron brackets. There are 82 lamps in all, 60 of the number being fitted with Welsbach incandescent burners, and the remaining overhead lamps on the bridge having ordinary burners with patent spreaders attached.

The presence of the old bridge on the site and the necessity of maintaining the traffic uninterrupted during the construction of the new bridge, influenced the engineer in the design of the structure, and brought about the decision to have two roadways. The bridge has, therefore, been built in two sections. Two of the three cylinders required for each pier were sunk on the east, or downstream, side of the old bridge, and carry half of the new structure. By fixing two of the girders of each span in position, and laying down the flooring, one roadway and the downstream footway were made ready for traffic. Fig. 6 is a view showing the work of erection in progress. A notable feature of the falseworks is the bowstring trusses used to support the main girders instead of continuous trestle-work. Two spans of these bowstring trusses were used for each 170 ft. bridge span, as will be seen from the illustrations. The first section or downstream half of the bridge was completed and thrown open for traffic without ceremony on Oct. 1, 1896, on which date the old bridge was closed and its demolition commenced. The erection of the second section, or upstream, half of the new bridge was then proceeded with and was completed and formally opened by His Excellency, the Governor, the Rt. Hon. Cord Lamington, K. C. M. G., on June 22, 1897, commemorating the Diamond Jubilee of Her Majesty, the Queen.

Mr. John McCormick was contractor for the piers and superstructure of the bridge, at $464,760, and Mr. Arthur Midson for the abutments and approaches, at $81,865, making the total contract price $546,625. The contracts were signed May 15, 1894. In addition to the above expenditure, upon construction the Bridge Board has expended $152,000 in the purchase of land used for widening the south approach.

THE AESTHETICS OF BRIDGE DESIGN AS EXEMPLIFIED BY TWO RECENT NEW YORK BRIDGES.

By Alfred P. Boller,* M. Am. Soc. C. E.

(With full-page plate.)

Supplementing Mr. Grimshaw's interesting account of European bridges from an architectural standpoint (Eng. News., June 17, 1897), I send you herewith two recent examples of American bridge building over the Harlem River, New York, N. Y., where a similar attention has been paid to aesthetic considerations. It is very gratifying that attention is being directed to the fact that bridges are very obtrusive objects in the landscape, and as such, cultivated taste requires that they be designed as sightly as the limitations of each special problem will permit, notwithstanding the fiat of

*27 Pine St., New York city.

FIG. 2. PORTAL OF CENTRAL BRIDGE WITH 40-FT. ROADWAY.

FIG. 3. JEROME AVE. APPROACH OF CENTRAL BRIDGE LOOKING EAST.

FIG. 4. EAST ABUTMENT OF CENTRAL BRIDGE, JEROME AVE. APPROACH.

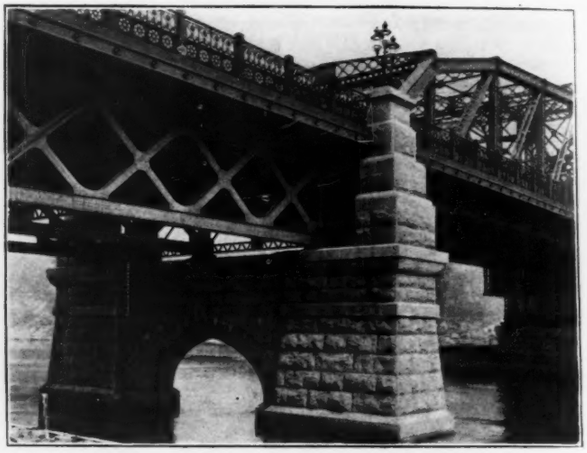

FIG. 5. REST PIER FOR HARLEM SHIP CANAL BRIDGE.

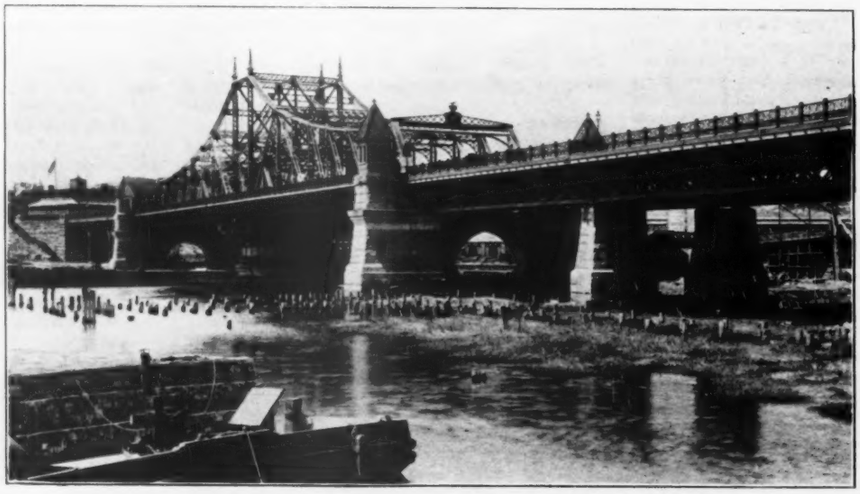

FIG. 1. GENERAL VIEW OF CENTRAL BRIDGE ACROSS THE HARLEM RIVER, NEW YORK, N. Y.

BRIDGES OVER THE HARLEM SHIP CANAL AND THE HARLEM RIVER AT KINGSBRIDGE ROAD, NEW YORK, N. Y.

Alfred P. Boller, M. Am. Soc. C. E., Chief Engineer.

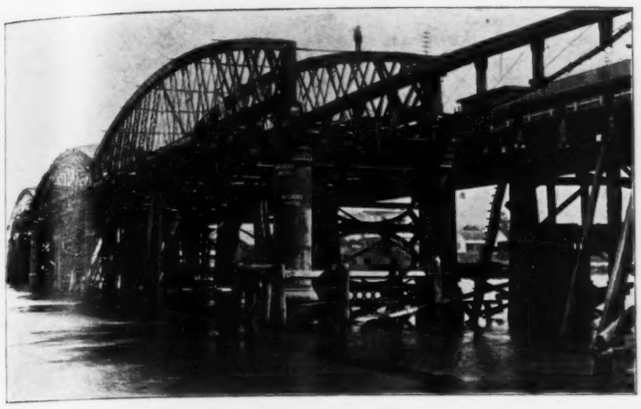

FIG. 6. VIEW SHOWING FALSEWORKS AND TRUSSES IN PROCESS OF CONSTRUCTION.

FIG. 2. VIEW UNDERNEATH BRIDGE SHOWING STEEL CYLINDER PIERS.

FIG. 4. VIEW OF ROADWAY SHOWING WOOD BLOCK PAVEMENT UNDER CONSTRUCTION.

FIG. 5. VIEW SHOWING STEEL TROUGH FLOORING FOR FOOTWAYS.

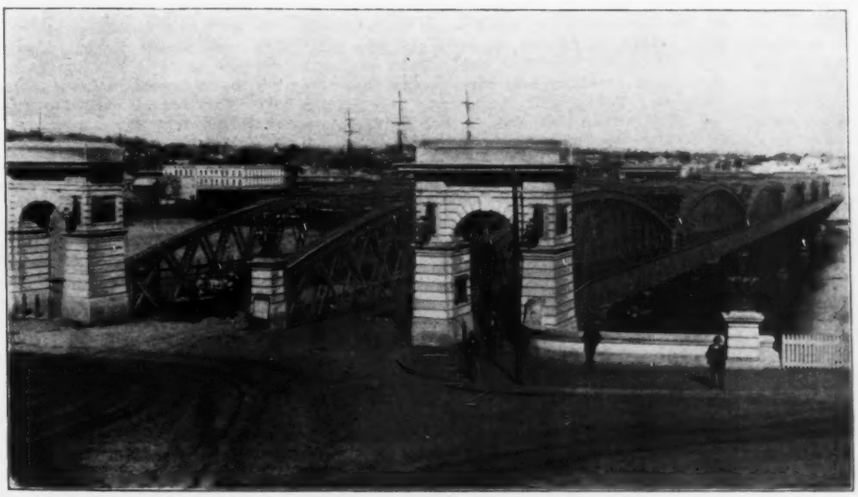

FIG. 3. VIEW OF BRIDGE SHOWING PORTAL ARCHES AND ENTRANCE TO CARRIAGEWAYS.

NEW VICTORIA BRIDGE, BRISBANE, AUSTRALIA.

Alfred B. Brady, M. Inst. C. E., Government Engineer for Bridges.
John McCormack, Contractor for Piers and Superstructure.
Arthur Midson, Contractor for Abutments and Approaches.

one of the leaders of the profession, that a bridge is simply a "tool" of transportation, and that anything in excess of constructive necessities, was out of keeping.

Such a principle, if principle it is, if carried to its logical conclusion, would eliminate grace and beauty out of existence, for any building is a "tool" in the same sense, being simply a housing for practical purposes, and only requires to be well-arranged within plain walls with a roof to shed water. In every age, as communities have become settled, and have reached a period where pioneer necessities were no longer absorbing, the instinct of men has turned toward beautifying their surroundings, and in proportion to their accumulated wealth, with the ambition, luxury and refinement incident thereto, has this instinct expressed itself in works of art, such as parks, fountains, buildings and bridges. American civilization has made giant strides since the centennial year in the development of the arts and sciences as applied to what we might call the adornment of existence.

There are probably no people on the face of the earth where ideas of taste and desire for beautiful things has so permeated the masses, as those of the United States. The concrete expression of such desires often takes on grotesque forms, but that is only in passing, and from time to time gives way to the expression of cultivated ideals, which bear the highest fruit in our chief cities, where the wealthy and the cultivated classes congregate, drawing to them the best-trained minds in all departments of human endeavor. The splendor of a city is made by its architecture in the broadest sense of the term, which is its outward and visible form, and when there are water-ways demanding bridge crossings, such crossings should be studied on architectural principles, as well as those of purely constructive engineering. Many definitions have been given as to what constitutes good architecture, but in the last analysis, the aims of the art must be classed under three heads, that of fitness, that of stability, and that of beauty; fitness, in the adaptation of a work to the requirements and limitations of the problem; stability, in the correct applications of constructive principles to physical conditions and the materials employed; and beauty, in so arranging forms, lines and colors as to excite agreeable emotions.

The first two of the qualities which have been named above, experience and technical knowledge supply, which are strictly engineering demands, and imply no sense of refinement or familiarity with the world of art or letters. But the last aim of architecture, that of beauty, calls for an entirely different mental equipment, and is based upon more or less familiarity with what the consensus of cultivated opinion throughout the world has selected as types of pleasing and attractive forms, coupled with an appreciation of the thought behind them, and their underlying principles. There are no empirical rules for beauty in building any more than for painting, nor is it easy to trace the sources of disgust or pleasure in the mind, on contemplating material objects. What is beautiful to some minds is unattractive to others, according to their mental endowments and opportunity for education in what constitutes true art. With education comes a change of sentiment, and what was once attractive may become offensive, or what was once passed by with indifference becomes a thing of beauty. There is no royal road to correct ideas in architecture, but public taste may be insensibly developed into right thinking by being surrounded with the masterpieces of the great designers. In truth, every building erected performs some function in affecting public taste, and the city that has the most buildings designed by men trained in the basic principles of true architecture, is the city where will be found the best public taste.

If this is true of the influence of good architecture as applied to buildings, it certainly applies with full force to bridges, which should have the same principles applied to them as other architecture. In constructions of this class, any notion that simple ornament constitutes beauty, or is the cardinal object of architecture, must be abandoned. Ornament, of course, has its place in architecture, but as applied to bridge design, it is rarely in keeping, excepting in railings or cornices, and even there should be used with wise discretion. Much otherwise good architecture is spoiled with overloaded ornament, and it takes very little to make a bridge appear ridiculous. In no other class of constructions is it so important to bear ever in mind that ornament should not be constructed, but the construction ornamented, and even then only in so far as it serves to accentuate a feature. Bridges as a rule are seen at a distance, and if of any magnitude, can only be seen in part when one is comparatively near, and therefore impress favorably or unfavorably the spectator by mass and general proportions. The detail is not seen, except under comparatively close inspection, but the lines and masses, the relations of the units to each other, such as proportions of piers and spans, down to subordinate relations of railing and cornice, are what gives character to such structures. Strong shadow lines are necessary to bring out strength and vigor of design, and, therefore, much attention must be paid to proportions and overhangs, copings and masonry forms. An arch bridge, whether a thrust arch or a tension arch, is the ideal basis for a beautiful structure, but is rarely possible on important water-ways, where girder forms must be adopted as "constructive necessities," and usually with draw or swing spans.

To treat such requirements architecturally is an exceedingly difficult matter, but it will always be found that some arrangement of panel lengths and chord lines will be more pleasing than any other, and this arrangement must be sought by careful comparisons. It will be usually found that the most sightly arrangement of diagram lines is on the side of true economy of material, like most things in nature, where we find economy and beauty linked together in exquisite harmony. Masonry may be made so effective by properly massing the parts, by straight lines and batter lines, by projection courses, copings, bridge seats, newals, and parapets, coupled with a judicious use and proportion of dressed surface to rock face, as to be worthy of the most careful study, remembering that shadow effects are what count in emphasizing masonry lines. There is hardly any masonry where the idea of base, shaft, necking, cornice and cap may not be kept in view and suggested in the design, a thought that is very helpful in maintaining proper proportions. A bridge often gives great opportunity for monumental or commemorative purposes, and when the approaches are well exposed, they may be designed with fine effect, affording points of advantage for the work of the sculptor in emblamatic statuary. Our civic architecture in this country has not progressed quite that far yet, although a commemorative bridge has been proposed over the Potomac River, at Washington, which some day will doubtless be built, affording a fine opportunity for a great work in bridge architecture.

It must be confessed that engineers, as a class, are not very successful in their attempts at architectural treatment of their constructive work, due not so much to lack of ambition, but entirely to their lack of training in that direction. Correct ideas of taste are not intuitive, and can only be developed by cultivation and contact with high standards. Some persons are born with a natural instinct for the beautiful, while others have no idea of proportion or beauty at all, and if there is an unsightly combination of lines or masses, they are sure to strike it. Unfortunately, most of us are vain in matters of taste and art, and consider it a reflection upon our ability to call in the aid of those who by instinct and training are qualified to supplement our deficiencies, which is a great mistake. I have long contended that our technical schools did not do right in turning out their young men without inculcating through lectures and illustrations, with a certain amount of personal drawing of typical forms, the great principles and truths of architecture. If they did, the result would in time tell upon our public works, and raise the profession of the engineer to a much higher plane.

In the Harlem Ship Canal bridge,* carrying Kingsbridge road over the canal, and in the Central bridge, over the Harlem River at 155th St., with the approaches thereto, I have endeavored to embody the principles of architectural bridge design above outlined. How successfully I have done so, it is for others to judge, but they were honest attempts to contribute as far as my reflections and studies would permit, to raising the art of the bridge builder to a higher plane than that of a simple constructor, and pay deference to what the community has a right to expect in its public works, viz.: thoughtful creations combining fitness, stability and beauty. Both bridges being very wide, considerable study was required so to arrange the masses that all ease and grace would not be lost in constructive necessities. Two trusses were adopted in each case, yielding wide and unbroken roadways, which permitted the adoption of twin piers, and in case of the ship canal bridge resulted in great foundation and masonry economies. By uniting the rest piers with arches, besides being a relief from the angularity of the pier lines, they support the middle girders of the approach deck spans in one case, while in the other, that of the Central bridge, they afford a passage-way to the landing steps beneath the arches, giving easy access to the river, which the adjacent bulkheads (yet to be built), will cut off.

The piers themselves carry out the ideas of column divisions, each having a shaft, necking, cornice and cap. The superstructure railing finishes at stone newals carried up from the pier caps on the ship canal bridge, breaking back by molded offsets from a broad base, while in the case of the Central Bridge, the railings finish in the stone refuge houses required for the end men, necessitated by the greater magnitude of the latter draw and nature of the traffic. These stone houses are designed in harmonious lines with the piers, the masses of which are accentuated by them, a spot of color being given by the red tiled peaked roofs.

The length of the ship canal draw being only 270 ft., it was difficult to arrange graceful lines for the trusses. A mistake was made in hipping the end panels, as they give a squat effect to the portals. In the case of the Central draw, the length of 408 ft. gave a fine chance to arrange graceful lines, and very careful study was made of the best proportions. The top chord is a continuous curve of eye bars from the ends to the centre, where it is crowned with latticed finials on the four centre posts, forming with the arrangement of panel proportions a harmonious combination of lines that I do not see could be bettered. A great deal of care was given in both structures to the study of the bracing, both transverse and lateral, so that the latticing and lines should be in harmony with the structure as a whole, decoration being sparingly indulged in, if shaped intersection plates at lattice intersections and corner brackets can be called decoration at all, but they are very effective in relieving the angularity of such constructions. The portals are not elaborate, are entirely of wrought metal and shaped and emphasized to be in keeping with the nature of the material and general design.

The overhanging sidewalks have substantial railings bounding them, with well molded cornices made from rolled sections, accentuated in the deck spaces with stamped metal rosettes at constructive intervals, except on the central draw, where the effect of the cornice depends on its boldness and shadow lines. The railings are substantial in effect, produced largely by the frequency of the newal posts and the solidity of the base. They are entirely of wrought metal, excepting the newel posts and bottom panelling, which are of cast iron, which last in the Central draw are of bronze, as is also the top rail. These railings were specially designed for these works, but on a plan of construction adopted by me some years since, in an effort to devise a system of railing at once simple in construction, substantial and neat in appearance, and, in fact, capable of a variety of ornamented filling that might be required for any special work.

The girders for the approach spans are clearly exhibited on the photographs, being latticed deck spans, in which relief from angularity is sought to be obtained by shaping the gusset and intersection plates in curves, about the only thing that can be done in the way of "decorating" lattice girders,

*Prof. Wm. H. Burr, Professor at Harvard College (now of Columbia University), was associated with me in the Harlem Ship Canal Bridge, and the work was officially carried on in his name.

in themselves not unsightly when well proportioned and arrranged.

More might be said in explaining the points of the approach masonry, abutments and the general lay out of the works, but it would lengthen this already too long communication. It is interesting to note, however, that the low lying, swampy tract traversed by the Jerome and Ogden Ave. approaches to the Central Bridge, as well as the upland from which the latter starts, will be eventually parked by the Park Department, which will add very materially to the appearance and finish of the whole work, and remove the unsightliness of the surroundings of the piers shown on the photographs.

A COMPOSITE BRAKESHOE OF STEEL AND CAST-IRON

An improved brakeshoe, which, from results thus far obtained, promises great advantages in point of economy and durability, is now being introduced by the Sargent Co., of Chicago, and is styled by its makers the "Diamond-S" shoe. The shoe consists of a body of cast-iron, in which are embedded sheets of expanded steel, a bundle of sheets being placed in the brakeshoe mold before the iron is poured. In order to insure strength and uniformity in the metal of the shoe, pig-iron alone is used for the casting. The expanded metal sheets are made from an excellent grade of soft steel, and the steel strands of these sheets are so fine that they become intensely heated when the molten iron is poured, with the result that a solid casting of uniform texture is produced. The expanded metal is less that 10% of the total weight of the shoe, and of itself develops little friction, but the hundreds of minute strands forming diamond-shaped meshes about ⅜ × 1 in. act as a network of barriers which prevent the granules of cast-iron from being instantly removed by the revolving wheel. It is this removal of the granules which causes the rapid wear of the ordinary shoe, but in the new form of the shoe the granules pass from mesh to mesh, being gradually reduced in fineness by reason of such obstructions, until they fall from the shoe as fine as dust, all the while retaining a granular form and developing the friction desired, without injury to the wheel. By this means the life of the shoe is about three times that of the ordinary cast-iron shoe, while its frictional efficiency is about the same as the latter.

Fig. 1 shows a set of expanded metal sheets ready to be inserted in the mold. Fig. 2 shows the general appearance of the face of the finished brakeshoe, the meshes in which are about ⅜ × 1 in. Fig. 3 is a cross-section showing the steel strands in the body of the shoe, and the angle at which these lie in relation to the face of the shoe and the tread of the wheel. This peculiar position is one of the special advantages of the shoe, since the wearing surface of the steel strands is but a knife edge, and as the position of the steel surface is constantly changing as the surface wears (as may be seen from Fig. 3), there is no chance for a hard spot to form and remain long enough to damage or groove even the softest steel tire. This feature results in giving uniform rate of wear over the entire width of the face of the shoe and the tread of the wheel.

These brakeshoes have been in use on a large number of railways (including some elevated railways) for about four months, with uniformly satisfactory results, one such shoe outwearing from 2½ to 6 ordinary cast-iron shoes, the rate varying according to the quality of the latter shoe. A fair average is said to be 1 to 4, and this applies to flange-bearing brakeshoes for driving wheels, as well as to the ordinary brakeshoes for cars.

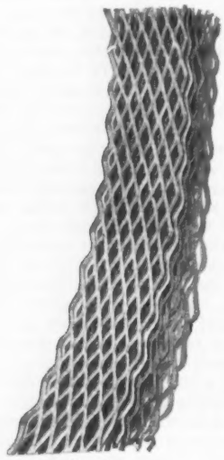

Fig. 1.

Fig. 2.

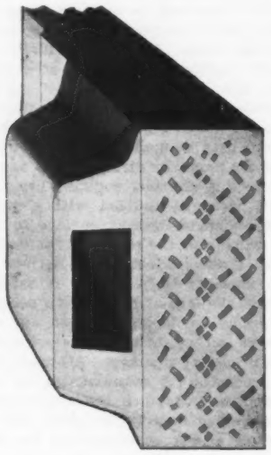

Fig. 3.

BRAKESHOE OF EXPANDED STEEL AND CAST IRON.
The Sargent Co., Makers.

REPORTS OF EXPERIENCE WITH COMPRESSED AIR MOTORS ON ELEVATED AND STREET RAILWAYS.

We are able to present to our readers this week several interesting papers bearing on the much disputed question as to the economical results obtained with compressed air motors on street railways. The first of these is a statement furnished to us by General Hermann Haupt, Consulting Engineer of the American Air Power Co., and the others are reports made to the Commissioners of the District of Columbia by engineers employed by them to report upon the system of traction which should be adopted upon the street railway lines of Washington. As our readers may recall, the street railway lines in Washington, like those on Manhattan Island, are unable to secure the assent of the local authorities to the use of the overhead trolley system. They are, therefore, practically compelled to choose between compressed air motors and an underground electric system, and their choice must be approved by the District Commissioners. The Eckington & Soldiers' Home and Belt Line railways, of Washington, have applied to the Commissioners for permission to adopt compressed air motors, and the Commissioners, before granting their approval, desire to satisfy themselves that this system will give a safe and reliable service, and that its economy is such as to enable the companies to conduct their business at a fair profit. It is recognized that the city has an interest in having its street railways operated by a responsible and solvent corporation, and that anything which might tend to delay the return to solvency of the companies whose application is under consideration would be objectionable.

We are indebted to the courtesy of Capt. W. M. Black, Engineer Commissioner of the District of Columbia, for the official reports which are here presented:

Statement by Gen. Hermann Haupt.

To the Editor of the Engineering News.

Sir: Requests have been sent to the writer for information in regard to the exact results of the tests made on the Manhattan Elevated Ry. with the compressed air motor. As these tests have developed the possibility of some improvements in details, it was not considered expedient to publish statements that might give erroneous impressions in regard to the full efficiency of the system. The steam locomotive of the present day is the result of more than half a century of development and improvement, and it would have been most unreasonable to expect that the air motor for elevated roads, involving the use of so many new inventions and novel mechanical expedients, should in its early trials be found so perfect in each of its details that no improvement could be found possible. Such a result would have been unprecedented in a mechanical construction of this character, but as reports have been circulated that the motor failed to fulfil requirements in a test to which it was subjected, it seems to be desirable that the facts should be given. So far from failure, the test demonstrated a most gratifying success for the system itself, but indicated the necessity of some slight changes in the details, the two most essential being an increase in the diameter of a ½-in. pipe leading to the motor cylinders, and the other, a change in the valve, which was found to be overbalanced, in consequence of which it lifted under pressure and allowed a considerable waste of air.

To give your readers an intelligible presentation of the subject, it is necessary to give a brief history of the Hardie motor of 1881: This motor was constructed at the Baldwin Locomotive Works in Philadelphia and was placed on the track of the Second Ave. Elevated R. R. at Harlem. The reservoirs were of riveted boiler iron, capable of sustaining a pressure of 600 lbs. per sq. in., and the reservoir capacity was 460 cu. ft. The motor cylinders were 12½ × 18 ins. The driving wheels were 42 ins. in diameter. The weight at the shop was 29,350 lbs., which was subsequently increased 2,500 lbs., making the total weight on the track 41,850 lbs. The pressure at starting at Harlem was 600 lbs.; at finish at South Ferry, 195 lbs.; consumption, 12,675 cu. ft. of free air, equivalent to 1,491 cu. ft. per mile, the distance run being 8½ miles.

The train consisted of four cars, and the total weight of the train was 81 tons. The train ran from Harlem to South Ferry in exact schedule time, making all the stops. There were present the Chief Engineer, Master Mechanic, and most of the officers of the road. The Engineer was taken from one of the regular steam locomotives. The test was a perfect success, and written certificates were given by all the officers present. Col. Hain, it is said, declined to give a certificate to Mr. Hardie in regard to the test, as he did not wish at that time to excite the public by any publication of the facts.

One of the strongest certificates was given by the engineer who ran the motor. He was delighted with its performance and declared that he had neither water nor fire to look after, and his view of the track was unobstructed by steam or smoke. There was sufficient reserve of air after the trip to run the motor light back to the engine house. Notwithstanding this successful test, the company was not ready to adopt compressed air and make a radical change in the equipment.

Mr. Hardie was soon after appointed Superintendent of the Rome Locomotive Works, and the writer, General Manager of the Northern Pacific R. R. The world was not yet ready for compressed air and no further efforts were made until 1892, when they were resumed, and the motors that have so successfully operated for a year on 125th St. are in part the result of these efforts.

In designing the motor for the elevated railroad of 1897, the results of former tests furnished the only available data from which to proportion the parts. The conditions presented were onerous in the extreme. The weight of the motor was limited to 47,000 lbs. and the weight of the train increased from 81 to 130 tons.

If the consumption of air be assumed as in proportion to the weight of the train, the required amount of air per mile, based on the results of 1881, would be 2,393 cu. ft. for a train of 130 tons; but a more accurate mode of estimating the volume of air would be to assume that it should be in proportion to the resistance to traction of the train, the motor requiring more power in proportion to weight than the cars. Assuming the resistance of the motor to be 40 lbs. per ton, for a weight of 23½ tons, and the car resistance 10 lbs. per ton for a weight of 105½ tons, the train of 1881 required 1,440 lbs. average traction and the train of 1897 would require 2,065 lbs. traction and 2,140 cu. ft. of air per mile, which, to allow a margin of safety, was assumed to be 2,400 cu. ft.

During the night of Sept. 1 the air motor was subjected to a very severe test in competition with a steam locomotive of somewhat heavier weight, which had been put in thorough repair. A train was made up of five cars and extra load was put upon the cars to represent 100 passengers per car. The seating capacity is only 48. The train was hauled successively each way by the steam motor and the air motor, stopping a prescribed length of time at each station. It was reported by an expert from Stevens Institute who was present that the steam motor, said to be 2,000 lbs. heavier, was taxed to its utmost capacity, that it did not reduce its speed to six miles per hour, as prescribed on a curve, and that it thereby acquired momentum to aid in ascending a grade at the end.

also that the fires were urged to the highest degree possible, a stream of sparks flying from the stack; notwithstanding these efforts the steam motor could not make schedule time.

The air motor stood the test without sticking fast. Its speed was kept down to the prescribed 6 miles per hour upon the curves. It lost more time than the steam motor during the entire run, being 8¼ minutes behind schedule time in going up and 6 1-10 minutes in returning and the consumption of air was largely in excess of the 2,400 cu. ft. estimated.

In discussing this result with Mr. Hardie, it appeared that the failure to make schedule time was due to insufficient diameter of the air pipe leading to the cylinder. In the motors operated on 125th St. the acceleration was as quick as could be desired, and, based on this experience, it was supposed that a ½-in. pipe for the elevated motor would be sufficient. It proved, however, to be not quite large enough. Of course it will be a very simple matter to substitute a larger pipe, and it should need no demonstration to convince any person of ordinary intelligence that the acceleration of an air motor can be much quicker than with a motor operated by steam. The pressure upon the piston of a steam motor is limited by the pressure of steam in the boiler, while in the Hardie motor the pressure can be instantly increased to 200 lbs. or more, if desired. The failure to make schedule time, therefore, does not indicate any defect in the system but only in a very simple detail which can be readily corrected.

As this motor had to be designed without a knowledge of the exact tests to which it would be subjected, o conditions to be fulfilled, it would have been a success beyond precedent if in these first trials no defects had been perceptible and no improvements found possible. So far from failure, the tests should be considered as demonstrating the complete success of compressed air as a system, for the defects are easily remedied.

Although the capacity for storage of the motor is limited to about 9 or 10 miles with a maximum train, the air system allows an indefinite extension by placing reservoirs under the passenger cars.

The officers and directors of the Manhattan R. R. exhibit a commendable prudence in requiring actual demonstration before any change of system will be authorized. If steam is to be superseded the choice must be between compressed air and electricity, and the proper test would be to require estimates for a full installation of such a line as the Third Ave. with maximum trains of 130 tons at intervals of 1 minute, and a guarantee from responsible parties that the line shall be installed and operated w... the estimated limits of cost.

The third rail system appears to give satisfactory results on one of the suburban lines of the New Haven Railroad, but its capacity is limited and the limit of its capacity on that road has been nearly reached. It would require many rails to transmit the current that would be required for the Third Avenue elevated R. R.

With independent motors, either steam or air, the results obtained from one motor can be depended upon for a thousand, and no outside construction, as in electricity, must be established and maintained with the constant menace to life, when, for economy in the weight of copper very high voltages are employed.

Comparative Estimates of Cost.

The data are not available for a full detailed estimate of the cost of plants and operation of the elevated roads of New York with steam, compressed air, and electricity, but they are sufficient to indicate a decided economy in the use of compressed air.

From the annual reports of the Manhattan Ry. Co., it is found that the number of locomotives is 335; the train miles per annum, 9,170,940; the cost of fuel, $900,022; repairs, $202,947; and the costs per train mile are: fuel, 9.8 cts.; repairs, 2 cts.; water, 1.17 cts.

The cost of compressed air is given in the published statements of the American Air Power Co. as 3 cts. per 1,000 cu. ft. of free air compressed to 2,000 lbs. per sq in., including maintenance, labor, fuel, and interest on cost of compressor station.

The average quantity of air consumed per train mile has been stated to be in proportion to the resistance to be overcome; a light train requiring less than a heavy one. It has been shown on the basis of the tests of 1881 that with an air motor in efficient condition the consumption of air for a maximum train of five cars, on the Second Avenue road, or on one of equivalent resistance, should not exceed 2,400 cu. ft. per mile. This estimate allowed 100 passengers per car or 500 to the train, but as the maximum number was carried only during a short period, morning and evening, the average weight of trains must have been less, and it is the average and not the maximum that determines the volume and the cost of the air required for operation.

It is probable, therefore, that less than 2,000 ft. should be considered a full average, but to avoid any question, the maximum of 2,400 cu. ft. will be allowed for all the trains, which will give for fuel and expense of power station, 7.2 cts. per train mile, saving 2.6 cts. as compared with steam.

The repairs of locomotives cost 3.2 cts. per train mile, but as there are no boilers or fireboxes on air motors, the repairs of which constitute the chief expenses, at least a cent and a half should be saved. The saving in water for steam may be estimated at ¾ ct. per mile. The aggregate of these three items is 4.85 cts. per train mile, or on 9,275,000 miles = $449,837 per annum.

In a comparison with electricity the difference would be much greater in favor of compressed air. In an estimate made by the writer, some years ago, on the lines of the ordinary trolley installation, maximum transmission of currents five miles and 500 volts at motors, the cost of a full electrical installation for trains of 130 tons at the one minute headway was found to be nearly four times as great as the equivalent with compressed air. This estimate was submitted to electrical experts for revision. Conceding that economics have been secured by recent improvements with excessively high voltage transmission, it is not and cannot be claimed that one-half the cost can be saved, and if it were, the electric plant would still cost twice as much as with compressed air.

As an illustration of the difference in cost of plant between compressed air and electricity in ordinary street car service, it may be stated that proposals having been invited for the equipment of the Eckington Road in Washington, D. C., the following proposals were submitted:

By American Air Power Co., compressed air....	$399,000
By Hoadley & Knight, compressed air....	508,000
By General Electric Co., underground electric..	1,795,105
By Westinghouse Co., underground electric.. ..	2,208,506

The air motors of the American Air Power Co., ran for a year on 125th St., to regular schedule, without the loss of a trip in all conditions of weather, and continued in full service when the cable and underground electric lines were blocked. The cost of plant and of operation with a full equipment of 364 cars was demonstrated from the daily records to have been less than with an overhead trolley (see reports in "Compressed Air" of March, 1897). The repairs of motors were covered by ¼ ct. per mile, notwithstanding the fact that no efforts were made to protect the motor machinery from dust.

With the data obtained from the operations on the 125th St. road, it is a very simple problem for any intelligent engineer to estimate the size of cylinders and the consumption of air on any other line to fulfil any required conditions and overcome any increased resistances; any grade within the power of a steam locomotive can be ascended with an air motor of equal weight. It is absurd to assume that the experimental stage has not been passed and that a year of trial must be demanded on every new road upon which it is proposed to introduce compressed air.

Herman Haupt.
Consulting Engineer General Compressed Air Co.

Report by Edward G. Emack.

To the Engineer Commissioner of the District of Columbia.

Sir: In compliance with your instructions with reference to the proposed adoption of the "Hoadley-Knight" System of Compressed Air Propulsion on the Eckington and Soldiers' Home and Belt Railways of this city, I beg leave to submit the following report:

(A description of the routes and grades of these railways is given, which we omit.—Ed.)

Weights of Motor Cars.

The weight of the air-motor car in use on the Eckington Railway is given by the officials of the company at 15,100 lbs., though Mr. McFarland states that he was informed by representatives of the Compressed Air Co. that the motor weighed about 20,000 lbs., and that it was billed by the railroad company at the time of shipment from New York city here as weighing 22,000 lbs.

The weight of the electric motor-cars on the Metropolitan R. R. of this city is estimated by the officials of that company from 15,000 to 16,000 lbs.

Since the spring of 1897 the officials of the above-named railways have been conducting experiments in compressed air propulsion under the above system, and claim to have obtained satisfactory results from the beginning.

During the past two months there has been received at the office of the Commissioners a number of protests from patrons and residents of the vicinities of said railways against the issuance of permits for their operation by compressed air as a motive power, citing as objections to such system its rejection in New York city after a thorough test, the disagreeable odor and heat from the fire-pot and stove-pipe passing through the car, the cloud of dust entering the car through the rear door and windows in dry weather, the oscillation and vibration of the car due to its great weight and working of machinery, the liability of the air-tubes or bottles to explode under the heavy pressure to which they are subjected, the noise of escaping air in starting and in ascending grades, and the inability of the car to make regular and uninterrupted trips over the various sections of the roads.

On or about June 10, 1897, the Superintendent of the Water Department, Mr. W. A. McFarland, was detailed by the Commissioners to inspect personally the construction and operation of the experimental cars in use on these lines, and to make a complete report thereon, which he submitted under date of June 24, 1897, supplemented by further reports on June 26 and 28, 1897. After giving a full description of the mechanism of the cars, Mr. McFarland states that "car No. 91" was on regular service between the power house at 4th and T streets, northeast, and 15th and G streets, northwest, making four round trips per day. The heaviest grade on this route being a short one of 5.25% at the upper end of Eckington Place; the next in importance being a long 3% grade on New York avenue. The length of this run and return is 5.4 miles and includes 16 curves.

On June 11 and 12 he reports four ordinary runs over this route (the motor-car being much impeded in its progress by the presence of horse-cars using the same tracks) in the average time of 46¼ minutes, a rate of about seven miles per hour, including stops averaging about one per minute. The car starting with an average pressure in the air bottles of 2,092½ lbs. per sq. in., and returning with an average reserve of 304½ lbs. per sq. in.

The compressed air is carried in seamless steel bottles under an initial pressure of from 2,000 to 2,300 lbs. per sq. in., gage pressure, and is fed through a reducing valve said to reduce the air pressure to about 200 lbs. per sq. in. on entering the high-pressure cylinders.

On the 12th instant the car was run over the Maryland and Washington track as far as the District line, where a probable speed of about 18 miles per hour was attained.

Car No. 400 arrived on June 16, and the first test run made on the 18th. On the 18th this car left the power-house with 2,225 lbs. gage pressure and made the trip to 15th and G streets, northwest, and return, with a fall in pressure to 250 lbs. On the third run the longitudinal brace under the motor struck a high place in the cobble pavement, at Florida Avenue and Eckington Place, and the car stuck fast, necessitating the use of a trolley car to free her.

On the 19th a run to Brookland and return was made; distance, 3 miles; maximum grade, 5%; fall in pressure, 750 lbs.

On the 21st a run was made from the power house to 7th and B streets, northwest, in 21 minutes. This run includes the most difficult grade (about 6%) on the whole system, on which are two sharp curves (viz.: on 6th Street and Louisiana Avenue, from C to 5th Street, northwest).

In ascending this grade on the return trip a failure to control the car occurred, the details of which are given in Mr. McFarland's report. It is proper to state in this connection, however, that Mr. McFarland, verbally, attributed this failure to the fact of the track at the head of the Louisiana Avenue grade being greasy prior to the test, and the car wheels becoming coated with grease in attempting to pass the curve slipped on the rails when the effort was made to descend for the purpose of securing greater headway.

Immediately after the above-named trouble the car went up the grade at a good speed and reached the power house with a reserve pressure of about 300 lbs.

On the 23d two trips were made, from Eckington to 15th and G streets, to Brookland, to Eckington, and from Eckington to Center Market, to Brookland, to Eckington, Starting with pressures of 2,300 and 2,250 lbs., running 8½ and 8 miles, and returning without incident, with pressures of 150 and 200 lbs., respectively. No passengers carried.

On the 25th this car, under full service conditions, carrying about 20 passengers, made the trip without difficulty from 4th and T streets, northeast, to Center Market, to Brookland, and return to 4th and T streets, making 37 full stops, including one in each direction on the heavy grade on Louisiana Avenue, between 5th and 6th streets. Starting with pressure of 2,050 lbs. and returning with 250 lbs. reserve, or sufficient for run of about three-quarters of a mile. Length of run, 8 miles.

On the 27th the same car successfully made the trip from 4th and T streets, northeast, to Center Market, to entrance to Catholic University, and return to 4th and T streets, carrying 46 passengers, in about 58 minutes; distance, about 7 miles. Pressure at starting, 2,000 lbs. Reserve at end of trip, 350 lbs., or sufficient for a run of about 1¼ miles. Made 34 full stops, including one at 6th and C streets, and again on Louisiana Avenue on the return trip, when restarting was done without difficulty.

Compressor Plant.

The compressor used for experimental purposes is a temporary affair answering fairly well for purposes intended.

The general plan of power plant and conduits, as outlined by Superintendent Todd, of the Eckington Road, consists of a central station near 10th and H streets, southwest. This location is selected to permit the use of river water, and would necessitate the use of at least two lines of pipe—one to the vicinity of 7th and B streets, northwest, and one to 13th and D streets, northeast.

In concluding the results of Mr. McFarland's investigation he finds the operation of the cars tested (Nos. 91 and 400), in the main, entirely satisfactory and suitable to the purposes intended, though he suggests a few minor changes in the arrangement of machinery, such as a slight enlargement of the diameter of the cylinders, and a reduction of wheel-bases of the cars.

The objectionable features of the fire-pot and stove-pipe in car No. 91 have been eliminated in car No. 400. The

vibration of the car while in motion he does not consider serious, though the noise from exhaust air in starting and in ascending grades is quite noticeable. The danger of rupture of air bottles, while not impossible, is improbable, and decreases proportionately with the distance from the charging point. The dust arising from the motion of the car is not appreciable.

Regarding the advisability of granting permits for the equipment of these lines with air-motors of the Hoadley-Knight pattern, it has been admitted by various authorities, and notably in an interview with Gen. Herman Haupt, published in the New York "Sun" of March 28, 1897, that this system was rejected in New York city in favor of the underground electric. It has not been tested on the various sections of the roads over which it is expected to be operated. It has not been demonstrated that these cars would carry sufficient excess of power to enable them to reach the charging point in case of loss through leakage or defective machinery, or to assist a disabled car to the power house. The length of time required for recharging the reservoirs at the proposed charging points is not obtainable. It is also stated, on fairly substantial grounds, that the people who are interested in these roads are also interested in this particular system of air-motors, and consequently desire its adoption. It seems proper that a schedule should be made public, and the cars run on such schedule for a period of several successive days. The fears of the public of danger from explosion of air reservoirs should be allayed by actual tests to the point of destruction, and results published. Has such a test been made of different systems as would ordinarily be required under similar conditions by railroad men wishing to adopt a change in motive power? Are the advantages offered for the adoption of the Hoadley-Knight system sufficient to warrant its selection in preference to others in view of the following facts?

In order to get the tracks of these lines in condition to render satisfactory service, and at the same time withstand the heavy traffic incidental to the use of the air motors, I have prepared an approximate estimate of the cost of such repairs, amounting to $81,430.

Under date of November 7, 1896, the president of the American Air Power Co., of New York city, submitted a proposition to equip the two roads in question with compressed-air motors of the Hardie system, consisting of 60 cars, provided with air-brakes, Pintsch gas appliances, storage capacity sufficient for a run of at least 10 miles, with a large reserve, capable of being operated at the rate of 10 to 12 miles per hour, together with a fully-equipped compressor and steam plant, exclusive of buildings, of sufficient capacity to run all the cars continuously, and to deliver the whole equipment ready for operation within six months of date of execution of contract, for $399,000. On the basis of 80 cars, however, the receiver has computed that their price would be $574,000, which would include an allowance of $30,000 for buildings and $12,000 for pipe lines.

To this amount, however, should be added the cost of track repairs as above ($81,430), making a total cost of equipment under the proposition of the American Air Power Co, $655,430.

Concerning this system, the Hardie, it is claimed to have been in successful operation on 125th St., in New York, for the past nine months, in all weathers and conditions, without interruption, and able to run when cables and underground trolleys were stalled by storm. Cost of operation is not obtainable, but Mr. Frank Richards, M. Am. Soc. M. E., in a letter published in the New York "Sun," of May 10, 1897, states that "it can be proven and guaranteed to be lower than that of any other known system."

Under date of November 9, 1896, the President of the Compressed Air Co. submitted a proposition to equip these lines with the Hoadley-Knight system, consisting of 80 complete car equipments (exclusive of car bodies), including Pintsch gas appliances, compressor and boiler plants (including building), storage reservoirs, pipe line, etc., complete, to be furnished within 12 months from execution of contract, for the sum of $508,000.

To this also should be added the cost of track repairs ($81,430), making the total cost of equipment under the proposition of the Compressed Air Co., $589,430.

A combined proposition from the General Electric, the American Wheelock Engine Co., and E. Saxton, was submitted for the equipment of the roads with an electric underground trolley system, similar to that in use by the Metropolitan Railroad Co., of this city, making the total cost for the equipment of the roads (according to the receiver's report), $1,791,105.

I have also prepared an approximate estimate of cost of equipping these lines with the same system as above, from data believed to be reliable, based on cost of the Metropolitan R. R., on the basis of 25.5 miles single track construction, 80 motor cars, 2 power stations, with complete equipments, including cables and all necessary adjuncts, etc., amounting to $1,443,000.

The Westinghouse Electric & Mfg. Co. also submitted a proposition for equipping the roads with the Electro-Magnetic system at a cost (according to the receiver's report) of $2,075,036, to which is added the estimate of the American Wheelock Engine Co. for steam equipment, amounting to $195,000, making the total cost of Electro-Magnetic system $2,270,036.

Summary of Cost of Systems.

American Air Power Co. (Hardie)	$655,430
Compressed Air Co. (Hoadley-Knight)	589,430
Underground Electric (receiver's estimate)	1,791,105
" " (private estimate)	1,443,000
Electro-Magnetic (Westinghouse)	2,270,036

In the matter of the selection of the Hoadley-Knight system for experimental purposes by the receiver, it is but fair to state that he claims to have been actuated by the fact of the act of Congress of June 10, requiring a test of compressed air propulsion be made, and that such a test could be made under the proposition of the Compressed Air Co., for a period of 30 days, without any expense whatever, other than the value of one car body, and without any obligation to adopt that system, such favorable terms not having been submitted by any of the other concerns from whom proposals were invited. And also its apparently successful and satisfactory operation on the Lenox Avenue line in New York city, and being particularly favorably impressed with its simple and effective system of control.

Regarding the comparative cost of operation of the compressed air and underground electric systems, it is difficult to reach a definite conclusion owing to the former never having been operated other than in an experimental manner, so that no reliable data are obtainable; although, in a communication to the Commissioners from R. J. Mawhinney et al. (No. 3397, Engineering Department), it is stated: "However, we understand that the expense of running one of these air motors (Hoadley-Knight) is about 14 cts. per mile, or the same as a cable car, while it costs but 9 cts. per mile for the underground electric." In an interview with the President of the Metropolitan R. R. Co of this city, he gives the operating expenses of their lines at about 9 cts. per car mile. These estimates, however, do not include the interest charges on the funded indebtedness connected with the different systems.

From the reports of the Railroad Commissioners of the State of Massachusetts for the year 1896, I have selected five of the street railways, operated by electricity (overhead trolley system), having the nearest approach in mileage of track operated to the Eckington and Belt lines, and find the average cost of operation, per car mile, of these five lines to be about 14½ cts.

Assuming, therefore, for the sake of comparison, that if the Eckington and Belt lines were equipped with air motors they could be operated at a cost of 14 cts. per car mile. With an equipment of 80 cars, 70 of which would be in constant operation for 18 hours per day at the average rate of 7 miles per hour, at 14 cts. per car mile, the yearly cost of operation would be $450,702, against $295,737 for the underground electric system under similar conditions, at the rate of 9 cts. per car mile, or an annual difference in favor of the latter system of $154,965.

Including the interest charges (7%) on cost of equipment under the Hardie, Hoadley-Knight and underground electric systems, a comparative statement would be as follows:

	Annual cost of operation.	Annual interest charges.	Total.
Hardie	$450.702	$45,880	$496,582
Hoadley-Knight	450.702	41,260	491,962
Underg'nd Electric..	295,737	101,010	396,747

The report of the Eckington road for 1896 shows 4,066,039 passengers carried, and of the Belt road for 1895 (report of the latter for 1896 not being available), 3,066,731, making a total of 7,132,731 passengers carried annually by the two roads, which at the rate of 4.59 cts. per passenger (the average of the Metropolitan R. R. of this city), would make the annual gross receipts from passenger traffic amount to $327,392.35. This, however, does not allow for a large percentage of increase in traffic which would undoubtedly result from the introduction of a rapid transit system on these lines.

But from reports of the President of the Metropolitan Railroad for the month of June, 1896 and 1897 (under horse and electric power, respectively), the gross receipts show an increase of 85% on the Georgetown line, and 70% on the Connecticut Ave. line. It would, therefore, seem reasonable to allow 50% increase for these lines. On this basis the gross annual receipts would amount to $491,088.52.

As to the advisability of the adoption of the Hoadley-Knight system of compressed-air propulsion in preference to the Hardie system, it is to be regretted that there are no data available showing very recent results of the experimental operation of the former in New York city. There are, however, a number of papers on file in the office of the Engineer Commissioner relative to the operation of a locomotive on this system as witnessed by Captain G. J. Fieberger, Corps of Engineers, U. S. A., on the tracks of the N. Y. Central R. R., at Rome, N. Y., February 21, 1895 (where a speed of about 18 miles per hour was maintained for a distance of 12 miles, and "not the slightest difficulty experienced in starting or stopping the car or regulating its speed"). See also communications of Gen. Herman Haupt (No. 4561) and Mr. Arthur W. Soper (No. 4926, enclosing copy of letter from the President of the Third Ave. R. R. Co. in New York city), all of which give most favorable reports of the operation of the Hardie Air Motor.

Very respectfully, Edward G. Emack.

Washington, D. C., July 16, 1897.

We append to Mr. Emack's report the following particulars of observations made by Mr. W. A. McFarland on cars of the Hoadley-Knight system, operated on the Eckington & Soldier's Home line, which are referred to above:

Tests of Car 91; Reservoir Capacity.

Date of run.	Distance, miles.	Pressure of air—In reservoir, lbs. At start.	At finish.	Cu. ft. of free air per mile.
June 11	5.4	2,050	300	
June 11		2,170	250	
June 11		2,000	250	
June 11		2,150	410	
Car No. 400; Reservoir Capacity, About 37½ Cu. Ft.				
June 18	5.4	2,225	250	
June 19	3			
Reservoir Capacity Increased to 44.2 Cu. Ft.				
June 23	8.5	2,300	150	
June 23	8	2,250	200	
Reservoir Capacity Increased to About 52 Cu. Ft.				
June 25	8	2,050	250	
June 27	7	2,000	350	

Notes: Each car has a seating capacity for 30 passengers and weighs about 20,000 lbs. Motors are compound; h.-p. cylinder, 3½ × 6 ins.; l.-p. cylinder, 7 × 6 ins.; gearing, 2 revolutions of motor shaft to one of car axle; wheel-base, 8 ft.; wheels, 28 ins. diameter.

Report of Capt. W. M. Black.

To the Commissioners of the District of Columbia:

Gentlemen: I have the honor to submit the following report upon the air motor system proposed to be adopted by the Eckington and Soldiers' Home and Belt Line Railway Companies.

The act approved June 10, 1896, requires the Commissioners to judge whether the compressed air motors experimented with or adopted by the Eckington and Soldiers' Home and Belt Ry. Companies "prove to be in all respects a proper and satisfactory motive power for the speedy and convenient propulsion of street cars."

The problem presented to the Commissioners is most difficult in the absence of the exact data to be obtained only from the experience of a line in regular operation. Claims, often unreasonable, are made for and against the system of air motor propulsion in general and the Hoadley-Knight system in particular. Under these circumstances it is to be expected that whatever the conclusion attained, the evidence presented will not be satisfactorily convincing.

To meet the requirements of the act, the motors in question must be safe, comfortable, sure in operation, and adapted to the work. Attention is invited to the accompanying reports of Assistant Engineers McFarland and Emack, which present details of great interest. From these reports the following deductions are made:

Comfort.—The features which the proposed cars have in common with all of the ordinary forms of street-cars may be considered satisfactory. Those peculiar to the car arise from the motive power. Heat and fumes of combustion have been complained of in the first type of car used, and with reason. In the second type the substitution of hot water for the furnace, it is reported, has removed these defects.

The noise produced by the machinery while in regular motion is not excessive. In starting and in ascending grades, the exhaust produces a puffing sound similar to that of a steam locomotive, but not loud enough to be seriously objectionable. The weight of the car is favorable to smooth riding, and the car vibration and pitching on the wheel-base in use (8 ft.) is not excessive. It should be noted, however, that this base is too long for the curves now in the lines and produces grinding and loss of power. It can be reduced, but if reduced may increase the pitching motion of the car. The dust thrown up by the exhaust has also been complained of, but apparently with slight cause, and this can be remedied easily.

A most important factor in the comfort of passengers is a solid track. The present tracks of the Eckington and Belt Railways were not designed for motors as heavy as the air motor, and probably would require considerable reconstruction before being fit for the proposed use. It may be added that a rigid track is necessary also to preserve the pavements adjacent.

Safety.—This comprises safety to passengers and safety to passers-by. The compressed air which provides the power is carried in from 31 to 37 seamless steel Mannesmann tubes, called bottles, with a capacity of 1.2 cu. ft. each, said to be tested to a pressure of 6,000 lbs. per sq. in. They are charged with air under an initial pressure of 2,000 to 2,300 lbs. per sq. in. This pressure is diminished as the run is made. The initial pressure is approximately equal to that caused by the complete combustion of about 4.5 lbs. of pebble powder per bottle. An explosion is possible, but not probable under normal conditions, and, barring accidents, the cars may be considered to be reasonably safe to the passengers. The risk of accident is not greater than on a steam motor. The machinery is easily controlled and the danger of foreseen collision is as slight as with an electric motor. In this respect the air motor must be considered safer than the

cable car. The effect on horses of the puffing of the car on grades cannot be foretold. It might easily startle a nervous horse.

Certainty of Operation.—The compressor machinery at the power station is liable to the same accidents as are common to all heavy machines, and like all machines from which a continuous amount of work is essential, must be partially duplicated at each station to secure the line from stoppages and delays due to breakdowns. When this precaution is taken and a proper reserve reservoir for air provided, there is no reason why there should be a stoppage of operation due to a failure of air supply.

Should the attempt be made to make substations for recharging, at which reservoirs are supplied through pipes from a main station, success becomes much more problematical. It has proved to be impossible to make gas mains under a pressure of less than 20 lbs. per sq. in. absolutely tight. It is very doubtful if long mains could be laid and maintained under the streets in such manner as to conduct air under the pressures proposed (2,000 lbs. and over) without so much leakage as to render the scheme commercially impracticable. The motor machinery on the cars is quite similar to that of a steam motor and may be considered as being well adapted to the end in view, if the propelling power (air) can be controlled to the same extent as steam. This remains to be proved.

In any system, occasional complete breakdowns of machinery are expected. In all other systems there is a sufficient reserve power in each motor to tow a disabled motor from any point on the route back to the power house. Mr. McFarland's tests show that the reserve of air in the motors in question is too small to provide for this contingency with certainty.

Fitness for the Work.—This includes the question of speed, power to overcome grades, curves, etc., convenience of location of power plant, and economic suitability. The first two requisites can be met if the motors can be supplied with air in quantity and at pressures sufficient for the work. The tests show that a car in working order, supplied with sufficient air at a proper pressure, can carry the required load up the worst grades on the road, and can attain the requisite speed.

It has not been shown, however, that trailers can be used with these motors. As traffic increases trailers play a most important part in the reduction of operating expenses, and in fact may be considered a necessity, especially where unusual transportation demands must be met on special occasions.

The air motor system seems the least flexible of systems as to the arrangement of its power plant. The shortness of possible run requires recharging stations at points on the line which cannot be changed to any material extent. The companies now propose either to establish three power plant houses or to establish one main power house with two substations supplied with air from the main station through pipes laid under the streets, but each having a reheating plant. Neither alternative is advantageous to the city. The latter is by far the more objectionable besides being of doubtful practicability.

There remains the economic problem. There are 31 miles of tracks in the combined systems. For a portion of the routes they pass through the busiest parts of the city. No system should be introduced which does not give a sure promise of commercial success. The needs of the district are too great to permit the risk of commercial failure and of the consequent breakdown of the adopted system. The use of compressed air as a motive power is not new. The real problem involved in its application to street cars is how to store asupply sufficient for a prolonged run without recharging. Given a supply of air under pressure the main loss of energy in its use, in a well designed machine, arises from the cold of expansion and leakage, and these causes of loss become greater as the pressure under which the air is stored and used is increased. Ordinarily air for running machinery is delivered at pressures of less than 100 lbs. per sq. in. In the motors in question in oris how to store a supply sufficient for a prolonged run reservoirs are charged with air at a pressure of more than 2,000 lbs. per sq. in. From these the air passes through a valve designed to reduce the pressure to 200 lbs. and thence it goes to the machinery, being reheated in order to increase its expansive power. It is the necessity for these great pressures that make the motors to a large degree experimental, and this is proved by the very great air consumption per mile, as detailed in Mr. McFarland's report. If this leakage and loss is so great with new machinery, run under the condition of a trial trip, what will it be when the valves and packing become worn? No data are presented, and none could be obtained in the tests possible to make, to show what would be the effects of wear, nor how much repair is required.

Mr. McFarland's report shows that the air motor system proposed is not economical as a machine. The average horse-power required to be developed per car from the approximate estimate he makes (the only estimate possible with the information attainable) is from about 43.7 to 44.4. The average horse-power per car to be developed in an electric line varies from 20 to 25. This would show in part the reason why the operating expenses per car mile should be relatively 14 cts. and 9 cts. for the two classes of motors, as mentioned in Mr. Emack's report.

To keep a road solvent the earnings must be sufficient to meet the operating expenses plus the interest on the bonded indebtedness. Thus, in two systems a cheap plant with large operating expenses may be less economical than a more expensive plant with small operating expenses.

Taking Mr. Emack's figures of the cost of equipping the roads with the air motor system and with the underground electric system, respectively, we have the following:

	Cost of equipment.	Int. at 7%.	Operating expenses.	Total.
Air motor	$589,430	$41,260	$450,702	$491,962
Underg'nd electric..	1,443,000	101,010	295,737	396,747

Difference in favor of underground electric system, $95,215.

The above figures are not claimed to be accurate. Accurate figures are not attainable.

In conclusion, it would seem that the air motor system possesses many good qualities, but that as yet it is experimental. Being experimental, good policy would seem to forbid its installation on so large a scale as the equipment of the Eckington and Soldiers' Home and Belt Railways would require.

The system may be "in all respects a proper and satisfactory motive power for the speedy and convenient propulsion of street cars," but satisfactory evidence that it is has not yet been presented. Very respectfully,

W. M. Black,
Captain Corps of Engineers, U. S. A., Engineer Commissioner, District of Columbia.
Washington, July 17, 1897.

Report of W. A. McFarland.

To the Engineer Commissioner, D. C.:

Sir: In accordance with verbal instructions, I have the honor to submit the following report on my inspection of the compressed air motor cars now in use by the Metropolitan Street Ry. Co., of New York city, and also of those formerly used on the 125th St. line.

At the time of my visit, August 19, 20 and 21, there were two compressed air cars, fitted with the Hoadley-Knight compound motors, on regular day service between Lenox Ave. and 146th St., and 109th St. and Columbus Ave.; the route followed being Lenox Ave. to 116th St., to Manhattan Ave., to 109th St., to Columbus Ave.

These cars and motors are the same in all essential respects as the "No. 400" now in use in this city; they are run in between the "underground electrics" with which the line is equipped. The total length of run out and back is said to be five miles, with a maximum grade of 7½% on 109th St. and a grade of about 3% on Manhattan Ave. Time occupied in making round trip 36 to 40 minutes; time for re-charging with air, 2 minutes; for re-heating water in heater, 10 minutes (the pipe used for introducing the steam for re-heating is small, and is said to be a temporary arrangement only; the time needed for re-heating can, without doubt, be much reduced by a re-arrangement in this particular). Each of the two cars in use makes about a dozen round trips per day, and during the time of my observation carried passengers, made the usual number of stops, maintained speed without difficulty, and climbed the steep grade on 109th St. at a rather better rate than did the electric cars. The passenger traffic was light and the weather favorable. The only point which seemed open to criticism from the passenger's point of view, was the puffing sound from the exhaust, which was quite noticeable in starting and in climbing grades, but which could not be heard when under headway on a comparatively level track.

The following statement, showing the fall of air pressure on each of the two cars inspected, indicates possible length of run under existing conditions:

Pressure in pounds.	Car. No. 411.	Car No. 426.
Initial	2,500	2,400
At end of 2½ miles	1,650	1,850
At end of 5 miles	1,300	1,625
Total loss	1,200	1,500
Reserve	1,300	900
Greatest possible run, miles.....	10	13

The difference in fall of pressure on the two cars is due to the greater reservoir capacity of 426.

In addition to the two cars at present in use there are three others in the shop at 146th St., intended for this service, two of them being already equipped with the Hoadley-Knight motors.

Piping.—There is a line of extra heavy 1-in. iron pipe laid in the electric conduit along the above-named route, for re-charging the cars at the southern end of the line, if necessary. This pipe line was not under pressure at the time of my visit, and I was informed that it had not been during the past summer. There is, however, about the power house at 146th St. a considerable amount of 1-in. and 1½-in. pipe under a pressure (gage) of 2,600 lbs. per sq. in. An inspection of some four or five hundred feet of this piping failed to disclose any evidence of leaky joints. I was assured by several employees about the station that no trouble from leaks had been experienced. The pipe used is said to be ordinary commercial "extra heavy" iron pipe, and is connected up with "tight joint" fittings.

The street cars fitted with Hardie compressed air motors, which were formerly used on 125th St., have been withdrawn from service and at the time of my visit were in the car barn on 125th St.

These motors are simple (not compound) with inside cylinders and outside cranks, the connection between main connecting rods and crank pins being through the medium of rocker arms and rock shaft. All working parts are close to the roadbed and exposed to dust and dirt; there are said to be over a hundred wearing parts so exposed, each requiring separate lubrication.

Mr. Hardie, the inventor of the motor, operated one of the cars for a short distance back and forth on the track in the car barn, and demonstrated the fact that the motor and car were under excellent control. The cylinders are 7 × 14 ins. The cars are shorter and lighter than those fitted with the Hoadley-Knight motors and used by the Metropolitan Street Ry. Co. The line on which the cars were used is practically level except for one short steep grade; length of round trip, 4¼ miles.

The following claims are made for these cars by the American Compressed Air Power Co.: A mileage of over 30,000 with practically no breakdowns and with a cost for maintenence of only ¼-ct. per car mile. A consumption of from 360 to 400 cu. ft. of free air per mile. That cars ran during heavy snow and sleet storms, when other surface lines were tied up, with an increased air consumption of only 20%, and an increase of 20% in number of passengers carried.

A hasty inspection was also made of the Hardie locomotive now being tested on the Manhattan Elevated Ry., and of the compressor plant on Greenwich St., used in connection therewith.

From this plant to the Rector St. station is a pipe line about 750 ft. in length, and 2.7 ins. internal diameter, used for conveying air from the compressors to the locomotive; this line was under a pressure of 180 atmospheres, or about 2,700 lbs. per sq. in., and showed no signs of leakage; the line is suspended from the elevated structure, and is everywhere in sight; it also is connected with the tight joint fittings mentioned above.

It is claimed by Mr. Pettee, engineer of the American Compressed Air Power Co., that the cost of compressing 1,000 cu. ft. of free air to 2,300 lbs. gage pressure at this plant is 2.75 cts.

I enclose herewith newspaper clippings giving account of test of Hardie locomotive used on elevated road. Mr. Pettee states that the free air per mile consumed on this run was 1,900 cu. ft.

On my return to Washington a few tests were made to determine the amount of trailer load motor car No. 400 was capable of hauling. The following is a synopsis of these tests:

Aug. 24.—Air Car No. 400, Electric Motor Car No. 23 as Trailer.

Weight of air car stated as	20,000 lbs.
" " electric motor car	15,000 "
Weight of train	35,000 lbs.

Route.—Power house to Brookland, to cut, and Florida Ave. to power house.

Power house	Pressure	2,400 lbs.
Brookland, 4:00 p. m.	"	1,625 "
4th and T Sts., 4.07 p. m.	"	1,250 "
Cut and Florida Ave., 4:12 p. m.	"	1,050 "
Power house, 4:17:30 p. m.	"	750 "
Distance run		4.3 miles.
Free air per mile		1,360 cu. ft.
Air car No. 400, weight		20,000 lbs.
Trailer, weight		6,500 "
Weight of train		26,500 lbs.

Route, same as above.

Pressure at start	1,800 lbs.
Pressure at finish	550 "
Distance	4.3 miles
Free air per mile	1,030 cu. ft.
Speed, per hour (mean)	10 miles.

On Aug. 25, car No. 400 hauled two electric motor cars, Nos. 5 and 23, from the power house at 4th and T Sts., N. E., to "cut" and Florida Ave. and return. Time, 11 mins.; distance 1.5 miles; maximum grade, 5%. Subsequently three box trailers were added to the train and hauled from 4th and T Sts. to 4th St. and Bunker Hill road and return. Time, 17 mins.; distance, 3.6 miles; maximum grade, 4¼%.

On Aug. 26 a train of eight cars, consisting of air motor No. 400, electric motors Nos. 5 and 23, and five box trailers, was hauled over the same route at a fair rate of speed. Total weight of train stated as 82,000 lbs.

Several trials show that the maximum speed of the air motor car, running light, is considerably in excess of that of the electric trolley cars on the same route; these speed trials were made in running up the grade on 4th St., N. E., from Albany St. to the top of the hill, maximum grade 4½%.

Very respectfully, your obedient servant,
W. A. McFarland.
Washington, D. C., Aug. 24, 1897.

REFORESTATION METHODS are to be introduced in Wisconsin under the direction of the State Forestry Commission. Inspectors from the northern part of the state have reported favorably upon the proposed plans, and Mr. B. E. Fernow, Chief of the U. S. Division of Forestry, agrees with the commission that the pine lands can be made to produce a second growth of marketable timber.

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Ship canal schemes are taking up considerably more space in the newspapers these days than the actual importance of some of them at least can warrant. There is renewed talk about a ship canal across the Michigan peninsula, from Lake Michigan to Lake Erie, but no reference is made to the fact that while a vessel was crawling along through such a canal, another vessel starting from Chicago at the same time, and running at full speed in the open lakes, could reach Lake Erie in a shorter time than the vessel which went by canal.

Another canal that seems little more likely to be built is that across Florida, which, according to its own promoters, would be 110 miles in length, and would cost some $70,000,000. Here again it is problematical whether a vessel would save time by using the canal compared with the time necessary to pursue the present route in the open ocean. Moreover, experience on other ship canals has proved that a very material saving of time is necessary for a canal to attract vessels. Owners of either sailing ships or tramp steamers are too much accustomed to delays due to weather, loading and unloading, waiting for cargo, and a dozen other causes, to be ready to pay heavy tolls to avoid a day or two's extra sailing.

In this connection we may also remark that the newspapers are wasting a good deal of space and making some misleading statements into the bargain concerning the adoption of this or that or the other route by the Deep Waterways Commission. As a matter of fact, we understand that this commission proposes to survey different routes and ascertain their comparative cost and advantages, and any announcement that it will adopt or recommend this or that route appears to us decidedly premature.

Legal difficulties between private water companies and cities have been notably frequent of late. This has been due to a variety of causes, chief among which are the ambiguous expressions which are found in many franchises concerning matters of importance, and the growing sentiment against the private ownership of public water-works plants.

In collecting information for "The Manual of American Water-Works" for 1897 an effort was made to learn the nature and extent of these legal difficulties, the question being put to each company whether there had been any such conflict between it and the city, and if so, what. Most of the companies reporting for the "Manual" made no answer to the questions. Of the 377 companies that responded, or regarding which information on this point was obtained in some other way, 124, or one-third, reported the recent or present existence of legal difficulties.

A somewhat rough classification of the nature of these difficulties shows that 39 involved questions relating to hydrant rental; 22 were occasioned by the construction or projection of municipally-owned works in competition with private plants; seven were over the purchase of private works by the city; another seven were over the quality of the supply, and six related to the pressure afforded; five had to do with the rates charged private consumers; and 38 were of a miscellaneous character, or the cause of the trouble was not stated. In some cases a number of points were involved, but the classification has been made in accordance with the most important point at issue.

The final outcome of 68 of the 124 cases was as follows: In 30 the city won; in 28 the company was successful; in ten a compromise was effected.

In many of the cases classified as relating to hydrant rentals, the primary cause was doubtless contention over the fulfillment or non-fulfillment of some part or parts of the franchise or contract, the city refusing to pay and the company suing for hydrant rental in consequence. In a number of cases decided against companies there was some irregularity or excess of power in granting the franchise, such as a failure to call an election for a popular vote on the grant, or a hydrant contract swelling the obligations of the city above the limits prescribed by law. Generally speaking, the courts always hold that a municipality must pay for water actually used, whether or not the franchise be void or irregular, except where there has been an excess of power. On the other hand, the cases have been rare, if any exist, where a company has been permitted to force a city to terms by depriving it of fire protection, the courts holding that life and property must always be protected from fire where that duty has once been assumed.

The most obvious lesson to be drawn from this litigation is that a large proportion of water-works franchises have been so loosely drawn as to be either extremely ambiguous or to leave loop-holes for an escape from responsibility on the part of one side or the other. Glittering generalities, such as provisions that the rates for public or private service shall not exceed the average of those charged in other cities, are a most fruitful source of litigation. Sometimes the contract requirements are extravagant for one on both sides, a city offering to pay for more hydrants and at a higher rate than its present or probable future condition warranted and the company also over-estimating the future. In rarer cases mere franchise-seekers have agreed to terms more liberal than local conditions warranted, for the sake of securing a franchise for speculative purposes.

A marked feature of franchise-making is the common lack of experience on the side of the representatives of municipalities, as compared with the experience of the attorneys and officers of private companies. This is natural, though deplorable and unnecessary, since a city seldom grants more than one water-works franchise, and the experience gained by one set of officials in handling some other franchise is entirely lost by the election of new men before another franchise comes up for action.

For the future, both cities and companies should exercise more care in framing franchises, while operations under them should be conducted in a spirit of fairness and equitable dealing on each side.

"Air Brakes Failed to Work," is the heading under which the daily papers of Sept. 30 reported a collision on the New York, New Haven & Hartford R. R., at New Haven, on Sept. 29, in which the engineer of the train lost his life. According to the newspaper reports, the engineer attempted to apply the brakes as usual as the train approached the New Haven station; but they failed to operate, and the train ran past the station at high speed and crashed into the locomotive of a standing train; the moving locomotive was derailed by the shock, ran 50 ft. or so, and then toppled over, crushing the engineer beneath it.

The air brake apparatus is so important a safety appliance that any such item as the above cannot fail to cause anxiety to any railway operating officer who appreciates the measure of his responsibility. The question at once arises whether the accident was due to a defect in the air brake apparatus itself, or to the error or fault of those in charge of it. In the present case the evidence appears to be conclusive that the latter was the case. When the engineer attempted to apply the brakes to stop at the New Haven station, the air pressure was practically gone from the reservoirs and the train pipe; and neither the venting of the train pipe by the engineer's valve nor by the conductor's valves which were operated in various cars in response to the call for brakes had any effect. It appears that a leak in the boiler reduced the steam pressure to such an extent that the train lost time steadily in making the run from New York, and it seems probable that the engineer attempted to save his steam pressure by closing the throttle of the air brake pump at some point on the run. Either he did this, or else the air pump governor became out of order; but even if this happened the engineer was at fault in neglecting to notice the fall in pressure as indicated on his air brake gage. It is stated, on good authority, that the fall in pressure in the train pipe and main reservoirs had been going on for at least a half hour before the arrival of the train at New Haven, and the engineer should have noticed it upon the gage. The air pump and governor were removed from the wrecked engine after the accident, and, without any examination, or repair whatever, were set up and operated. They were found in perfect order, and the governor repeatedly started and stopped the pump automatically and accurately in response to varying pressures in the air reservoir. This appears to be convincing proof that the cause of the absence of air in the air brake system was the closing of the air pump throttle by the engineer.

Here is a case worth careful study by railway officials who still cling to the idea that safety in railway operation is to be found in the vigilance of employees rather in the use of automatic appliances. The engineer whose negligence caused this wreck, and who paid the penalty with his own life, was one of the most trustworthy and reliable engineers on the New Haven road. He was a man of mature years, who had had the most responsible express train runs. He was one of the engineers of the famous "White Flyer" train which was run on the New York, New Haven & Hartford some years ago. And yet this thoroughly capable and trustworthy engineer brings his train into a station at 60 miles an hour with no air in the brake system to make the stop!

We believe the lesson that should be drawn from this accident, and from other similar accidents which have been noticed in these columns in the past, is that the presence of air in the train pipe is of too great an importance to the safety of a fast express train, at least, to justify the continued sole reliance on the air pump governor and the engineer's watchfulness to ensure this pressure being maintained. There should be an automatic alarm whistle on every car which would give audible and continuous warning to the train crew whenever the pressure in the train pipe is reduced to the danger point. Such a device might be of the simplest character, and need in no way complicate the ordinary operation of the braking system. We believe that there is not a railway officer responsible for the safe movement of trains who would not feel an added sense of security if he knew that on all his passenger trains the conductor and brakemen, as well as the engineer, would have audible warning of the loss of pressure in the air brake system.

In the description of the Scherzer rolling lift bridge at North Halsted St., Chicago, Ill., published in our issue of Sept. 9, an error was made in one of the sub-captions to Fig. 1, by giving the name of the contractors as the Scherzer Rolling

Lift Bridge Co. The contractors for the superstructure were the King Bridge Co., of Cleveland, O., and for the substructure, Wilson & Jackson, of Chicago, Ill., as was correctly stated in the body of the article.

THE COMPARATIVE ECONOMY OF COMPRESSED AIR AND ELECTRIC TRACTION.

The series of papers printed elsewhere in this issue concerning the use of compressed air for the motive power of elevated and street railways furnishes some data which may be useful in the discussion of the question whether or not compressed air offers enough advantages over electricity to warrant its extensive adoption for urban railway traction.

Gen. Haupt's letter presents some figures showing the cost of steam locomotive traction on the Manhattan Ry., in New York city, which may be accepted without further argument as showing the superiority of compressed air to steam for motive power on such a railway. Steam locomotives need no longer be considered as in competition with either air or electricity. Their high cost for fuel, water and repairs, together with the nuisance they maintain in the streets of a city, put them out of the race. The question now is not between steam and air, but between air and electricity.

We agree with Gen. Haupt's statement that the data are not available for a full detailed estimate of the cost of plants and operation of the elevated railways of New York with steam, compressed air and electricity, but we are not yet prepared to agree with his further statements that the data are sufficient to indicate a decided economy in the use of compressed air as compared with electricity. The case for compressed air remains to be proven, and more data than are yet available must be procured before the proof can be made.

The first question that arises concerning the relative merits of compressed air and electric traction is the relative cost of fuel, or what practically amounts to the same thing, the relative efficiencies of the two motive powers. In both systems we begin at the coal pile, and waste a certain amount of the heat energy in raising steam and in using it in steam engines. In both systems the cheapest fuel may be used. The kind of boilers and engines may be the same, the location of the central station at a point where fuel and ashes may be cheaply handled may also be the same, and the indicated horse power in the steam engines may be obtained at the same cost, or perhaps slightly less with the compressed air system, since the momentary variations of load upon the engine are much smaller. But in the transformations of energy which occur between the engine cylinder and the car axle, the efficiencies of the several parts of the apparatus of the two systems vary considerably, and more experimental data than are yet available are needed before an accurate comparison of efficiencies can be made.

In regard to the efficiency of compressed air the following computation has been furnished us by Gen. Haupt:

Efficiency of Compression to 2,000 lbs. per sq. in. and Reduction to 100 lbs. per sq. in. in Air Motor.

		HP.
To compress 1 ft. free air per min. to 2,000 lbs. per sq. in. requires		0.40
To compress 1 ft. free air per min. to 100 lbs. per sq. in. requires		0.17
Loss in wire-drawing		0.23
0.17 ÷ 0.4 = 42.5% utilized; 0.23 ÷ 4 =	57.5% lost.	
Efficiency of compression		80%
Utilized of this		42.5%
Net efficiency, .425 × .80 =		34.0%
Doubled by reheating		68.0%
Efficiency of motor		80%
Net efficiency of motor, .68 × .80 =		54.4%

It will be observed that the above computation assumes that the efficiency is doubled by reheating, but no account is taken of the cost of this reheating. We may supply a rough estimate of this cost as follows: The efficiency can only be doubled by doubling the volume of air entering the motor, the pressure remaining constant, and this would require the temperature to be increased 460° F., 1 cu. ft. of free air weighing 0.08 lbs., and its specific heat being 0.24, heating it 460° F. would absorb 0.08 × 0.24 × 460 = 0.873 B. T. U., which is equivalent to 0.873 × 778 = 680 foot ponds of work per minute, or 0.021 HP. It would require a very good heating furnace to give an efficiency of 50%, so to furnish this 0.021 HP. to the air in the motor would call for a fuel consumption equal to the heat equivalent of 0.042 HP. The compression of the 1 cu. ft. of air per minute required originally the expenditure of 0.40 I. HP. in the cylinder of the steam engine. To this should be added the cost of reheating, or 0.042 HP., making 0.442 HP. The motor delivers, according to Gen. Haupt's figures, 54.4% of 0.40, or 0.2176 HP. Dividing this by 0.442 gives an efficiency of 49.2%, instead of 54.4%.

Gen. Haupt's figures assume an efficiency of 80% for the motor. There is no doubt that this efficiency may be obtained in a well-constructed motor when it is operated at or near its most economical load, but the load on a locomotive is exceedingly variable, and its efficiency must vary within wide limits as the load varies from minimum to maximum. We should consider it remarkable if the efficiency should average as high as 80% for all conditions of loading.

It may be interesting to compare the figures given above to those which were published extensively some years ago concerning the operation of the Popp compressed air plant in Paris. In this plant the air was compressed only to 6 atmospheres (absolute), or 73 lbs. per sq. in. gage pressure, and consequently the operation did not entail nearly so great a loss due to cooling of the compressed air as if it had been compressed to 2,000 lbs. per sq. in. On the other hand, the efficiency of the compression machinery and of the motors were both lower than those given in Gen. Haupt's statement, and the reheating caused a gain of less than 40%, instead of 100%.

The figures for the Paris plant are as follows:

Efficiency of a Compressed Air Power Plant. From Tests of the Popp Compressed Air System in Paris, 1891.

1 I. HP. at central station engine = 0.845 I. HP. in compressors.

This corresponds to the compression of 348 cu. ft. of air per hour from atmospheric pressure to 6 atmospheres absolute.

This 0.845 I. HP. will deliver as much air as will do 0.52 I. HP. in adiabatic expansion after it had fallen to the normal temperature of the mains.

0.52 I. HP. power of the air at the station, reduced to
0.51 " by fall of pressure in the mains (5 kilometers)
0.50 " by fall of pressure to 4½ atmospheres (absolute) in the reducing valves,
0.39 " by incomplete expansion, wire-drawing and other causes, reducing the actual I. HP. of the motor, when the air is used cold, to 0.39 I. HP. This is increased by heating the air to about 320°F. to
0.54 " Ratio of gain = 0.54 ÷ 0.39 = 1.38, supplied by the combustion of about 0.30 lbs. of coke per I. HP. per hour. If this be taken into account, the real efficiency of the whole process becomes 0.47, instead of 0.54.
0.47 " obtained in motor from 1 I. HP. in steam engine in central station, taking into account cost of reheating the air.

Indicated efficiency of motor.....0.39 ÷ 0.50 = 0.78
Indicated efficiency of whole process with cold air....0.39
Apparent indicated efficiency of process, heated air...0.54
Real indicated efficiency, whole process, with heated air0.47
Mechanical efficiency of motor.....cold, 0.67; hot, 0.81

The final indicated HP. of the motor is only 47% of the indicated HP. of the steam engine, or 2% less than the figure given by Gen. Haupt (after we have revised it for the cost of reheating), for the net efficiency of the motor. If the mechanical efficiency of the motor, as given in the French figures for hot air, is 0.81, then the mechanical power delivered by the motor for each 1 HP. in the steam engine is only 0.81 × 0.47 = 0.38 HP.

For a fair comparison of the computed efficiency of the compressed air system with electrical traction we may take the data given in Mr. M. H. Gerry's recent paper on Electric Traction on the Metropolitan Elevated railway of Chicago, published in our issue of Sept. 16, 1897. For a 4-car train running at an average speed of 13.3 miles per hour, including stops, with an average current of 138.3 amperes and 504 volts at the train, he gives for the electrical HP. at the generating station 101 HP., transmitted to the train 93.4 HP., and utilized in propelling the train 51.5 HP., making an efficiency of 51% from the generators to the car axle. Taking the efficiency of the generators at 92%, which Mr. Gerry gives as a fair "all-day efficiency," the I. HP. used by the generators would be 101 ÷ 92 = 110 I. HP., and the net efficiency from the engine to the car-axle 51.5 ÷ 110 = 47%.

If we may admit that it is possible by the use of very efficient compressors, reheating furnaces and motors to realize with compressed air a net efficiency at the car-axle, under conditions of fairly uniform loading, of 49%, the best that can be said in favor of the fuel economy of the compressed air system is that it is equal to that of the electric system as used in Chicago. Whether it should be used in preference to electricity will then depend upon other conditions than its fuel economy. These conditions will vary on different lines of railway. On a level road with a long distance between stations the energy exerted by the motor will be approximately constant; a most favorable condition for the air motor. With frequent stops and frequent sharp grades the energy exerted will vary from zero to the maximum of which the motor is capable. This condition is easily met by electric motors. It seems to us a question whether it can be well met by air motors.

In the cylinder of the air motor, as in that of the steam engine, there is a point in the stroke at which the cut-off must take place in order to give the maximum economy. With a very early cut-off, corresponding to light loads, the air will expand to a pressure below that of the atmosphere, producing an indicator card with what is known as the "loop diagram." With a heavy load, such as that due to climbing a grade or to accelerating the speed, the card will have a high terminal pressure. Both of these conditions mean low economy.

Even if the question of fuel economy may be shown to be not unfavorable to the compressed air system, there are questions concerning the practical operation of air motors in which electric traction seems to have an advantage. In a high speed rapid transit line with frequent stops, rapid acceleration of speed is of the utmost importance. With an air locomotive this requires great weight for adhesion, and large cylinders to supply the power. Large cylinders, proportioned for economical use of air at maximum loads are very wasteful at light loads. Part of this disadvantage may be overcome by using moderate-sized cylinders, and very high initial pressures for heavy loads and reducing the pressure for light loads, but it will require a long series of experiments to determine what sizes of cylinder and what initial pressures should be used for different conditions of running to give the maximum economy. In electrical traction the great weight of locomotive necessary for adhesion is avoided by dispensing with the locomotive and by using the weight of the motor car for adhesion. In the Sprague system, with a motor on each car, the required adhesion is easily obtained, and at the same time the maximum power of all the motors is available for rapid acceleration. It does not appear probable that any system of air locomotive traction can compete with the Sprague system in giving the acceleration which is so important in elevated railway service.

On the other hand, compressed air traction has some features of advantage over electric traction. One is its facility for storing power during times of light loads, without any cost of deterioration of the storage apparatus, which is the great defect of the electric storage battery. It is likely, however, that any large storage capacity could be obtained only at great cost of installation. Another, and probably the most important, as appears from the estimates of cost given in the reports on the proposed installation in Washington, is a lower first cost of plant, and consequent interest charge. These estimates, however, are for a surface street railway, in which the underground trolley system and the electro-magneitc underground system are the only systems of electric traction proposed. For elevated railways the third-rail system, which is no doubt vastly cheaper in cost of installation, would probably be used.

For an existing line of elevated railway, such as those in New York and Brooklyn, where steam is now used, and a change to electric or to air traction is contemplated, it would appear that air traction might be introduced tentatively, in an experimental way, at a cost, and an inconvenience to traffic while making the change, far less than that required to introduce electric traction. A small compressing plant might be built and a few air locomotives used which could take the place of a few of the steam locomotives. An accurate account of the cost of the operation of the air locomotives could be kept and compared with the cost of operating steam locomotives, and with the cost of electric traction on the Chicago elevated railways. A six months' trial on a moderate scale should be sufficient to settle the relative merits of

steam, air and electric traction, and then if air traction should be found the best, it would be easy to enlarge the compressing plant and to build more locomotives, with such modifications in the original design as the results of the experiments might indicate.

TEST OF A FOUR-STAGE AIR COMPRESSOR AT PRESSURES UP TO 2,500 LBS. PER SQ. IN.*

By K. E. Stuart and H. L. Terwilliger.

The compressing plant of which this thesis treats is located at No. 100 Greenwich St., New York city, and the chief object of its construction is to supply high pressure air for use as motive power in the Hardie compressed air locomotive, now being tried on the Manhattan elevated railway.

The plant consists of a new type of four-stage compressor, built by the Ingersoll-Sergeant Drill Co. This is run by two simple Corliss engines of the non-condensing type, with cylinders 18 × 36 ins. The compressors are directly connected to the engines by coupling the piston rod, produced, of the engines to the piston rods of the compressors. The two low stage compressors are connected to one engine and the two high stage to the other, and the engines themselves are connected by cranks at 90° to the same shaft, on which is a 16-ft. fly-wheel weighing about 15 tons.

The compressor consists of four single-acting air cylinders, of the following dimensions: Low pressure, 21¼ × 36 ins.; first intermediate, 9 × 36 ins.; second intermediate, 7 × 36 ins.; high pressure, 3 × 36 ins.

A very complete cooling system is provided for this compressor. The low and the first intermediate cylinders are surrounded by a water box, as are also the second intermediate and the high pressure cylinders. There are also three intercoolers and one aftercooler. The first intercooler is between the low and first intermediate cylinders, and consists of a cylindrical box about 18 ins. in diameter and 7 ft. long, containing tubes through which water is kept flowing; the air circulating around these tubes is cooled by the contact. The second intercooler is between the first and second intermediate cylinders, and in appearance is like the first, but the air flows through the tubes and the water around them. The third intercooler is between the second intermediate and high pressure cylinders, and consists of a helix of copper tubes placed in the water box with the second intermediate and high pressure cylinders. The air passes through the aftercooler just after the fourth compression; this also is a helix of copper tubes surrounded by a cylindrical water box about 4 ft. high and 30 ins. in diameter. To make the cooling more complete, the piston rod stuffing-box of the second intermediate cylinder is also water-jacketed.

The tank in which the air is stored after compression is made up of 144 Mannesmann tubes, 24 of which are 21 ft. 6 ins. long, with a diameter of 9 1-16 ins., the metal being ½-in. thick. The remaining 120 tubes are 15 ft. 6 ins. long, with the other dimensions the same. The total volume of this reservoir and connections is about 925 cu. ft.

Owing to the limitations of space, no boiler could be put in this plant, so that the supply of steam has to be taken from the street mains of the New York Steam Co., and this necessarily insures very unsatisfactory conditions for the steam end of the plant, the maximum pressure being only about 80 lbs. per sq. in., and the steam containing a large amount of water.

The water supply for the boxes and intercoolers is obtained from the city mains primarily, but the expense of this method of cooling is evident, and to avoid it a method of using the water over and over is applied. In the cellar, two large tanks, 20 ft. long, 10 ft. wide, and about 5 ft. high, were placed for storing the water. From these it was pumped through the system of jackets and around into pipes over the tanks, which were drilled full of small holes, thus discharging the water back into the tanks in a great number of streams, and cooling it meanwhile.

The supply of air to the compressor is taken form the cellar, and drawn over these tanks through window-like openings into a small room, to which a wooden conduit about 18 × 12 ins. leads from the low pressure cylinder. Air is taken into the low pressure cylinder through a piston inlet valve, and compressed to about 55 lbs. gage pressure, and discharged through spring valves into the first intercooler. From here it passes to the first intermediate cylinder, and so on through the system. All valves after the low pressure cylinder are operated by the back pressure upon them, so that none of the three last cylinders begin to compress until the pressure in the receiving tanks exceeds the pressure in the cylinder or the intercooler next below.

The pressures, by gage, at which the respective cylinders are designed to deliver the air are: Low pressure, 55 lbs.; first intermediate, 160 lbs.; second intermediate, 780 lbs.; high pressure, 2,500 lbs.

A good method of oiling is provided for all cylinders, so that wear shall be reduced to a minimum. At the time this test was made the machine had been run only a part of the time for a week, so that it could hardly be expected to get as satisfactory results as if it had been in use longer.

Plan and Theory of Test.

According to the first law of thermodynamics heat and mechanical energy are mutually transformable one into the other, the ratio of this transformation being very nearly 778 ft. lbs. of work for one British thermal unit. This law, when applied to the high compression now being dealt with would, if no cooling took place, give a temperature nearly sufficient to melt common cast-iron.

Compression without cooling is called adiabatic, and could the air be used as soon as compressed it would be an ideal method, for, as the air did work it would expand adiabatically, thus returning 100% of the energy supplied. It is, however, in most cases impracticable to use air as soon as compressed, and it is, therefore, allowed to cool, thus losing an amount of work directly proportional to the fall of the temperature of the air. It has been found that on account of this loss it is much more economical to keep the air as cool as possible while compressing, thus doing so much less work to get to the final pressure that would be attained after cooling the air that was compressed adiabatically.

When the cooling is perfect, that is, when the temperature of the air remains the same throughout compression, isothermal compression, so-called, takes place. This might properly be called the ideal compression, for it is the goal that all compressors of to-day are designed to approach as nearly as possible. This serves well to illustrate the necessity of efficient cooling during compression.

The advantage of having the intake air at as low a temperature as possible will be readily seen. It has been found that in starting adiabatic compression from 0° and 60°, respectively, the final temperature, when 2,500 lbs. is reached, will be 260° higher in the latter than in the former case, or in words, the higher the initial temperature the more rapid is the increase of temperature with increase of pressure.

The temperature at intake has other effects than on the final temperature of the air, namely, in varying the efficiency of the machine. If under constant atmospheric pressure, air is taken for the compressor from a hot engine-room, the efficiency is greatly lessened, due to the decrease in the density of the air. To make a test of a compressor it is necessary to ascertain how well it is utilizing the power supplied it, and how nearly the temperature ranges are kept to the ideal isothermal. To do this one should have, aside from the cards of both steam and air cylinders, the temperature of air at beginning of compression, the temperature of air before and after each cooler, and the temperatures of all jacket water before entering and at leaving each jacket.

Preparations for Testing.

After a careful outline of what it was desired to accomplish had been laid down, each object sought was taken up by itself, the necessary data analyzed, and plans formulated as to how they were to be obtained.

The first difficulty foreseen was the taking of cards from the last two compression stages, ending in 750 lbs. and 2,500 lbs. respectively. For this purpose two Thompson indicators were especially fitted by Mr. W. F. Raymond. The change consists in an extension of the indicator barrel having a reduced bore so as to accommodate a piston much smaller than the ordinary. In the high pressure indicator a 250-lb. spring was used, with a piston 0.1 sq. in. in area, making a nominal scale of 1,250 lbs. to the inch. The indicator for the second intermediate stage was fitted with a piston having an area of ¼ sq. in., and a 200-lb.

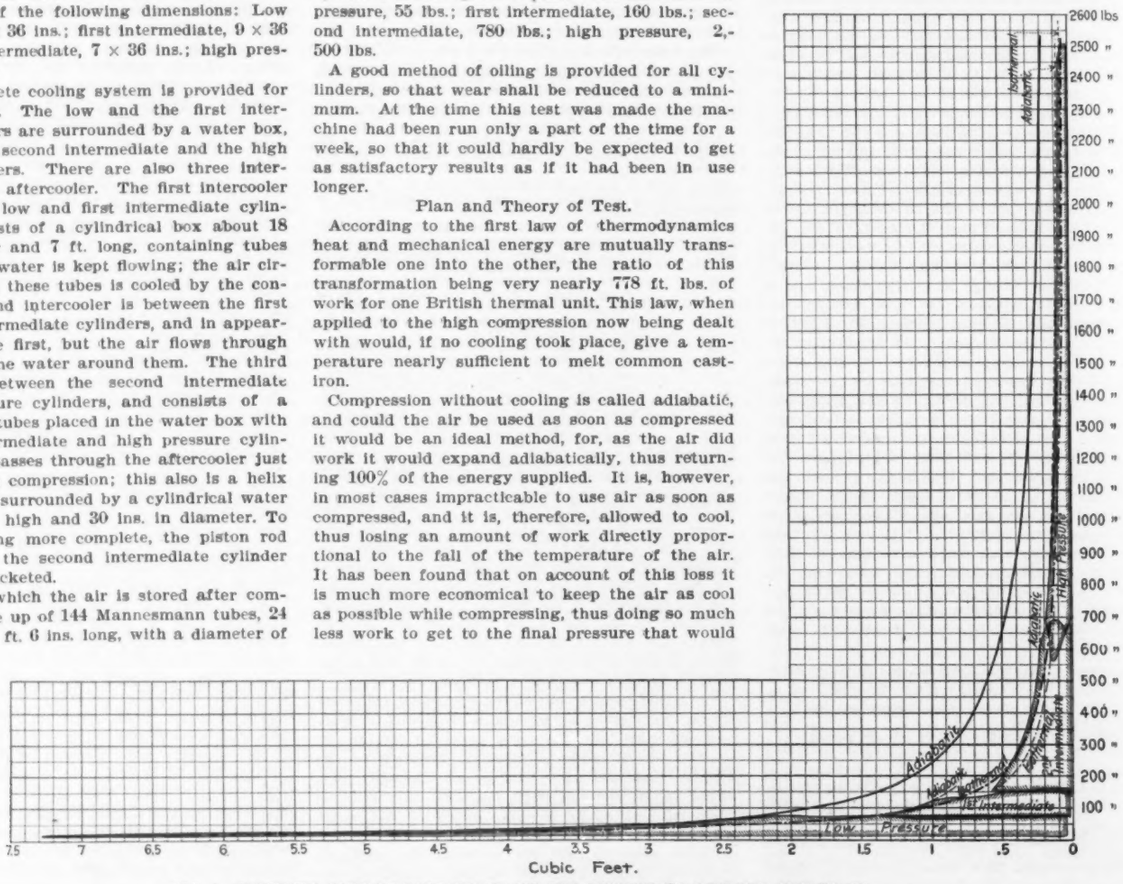


FIG. 1.—COMBINED CARD OF FOUR-STAGE AIR COMPRESSION TO 2,500 LBS. PER SQ. IN.

*Condensed from a graduating thesis at Cornell University.

spring, making a nominal scale of 400 lbs. per in. on the drum. A careful computation relative to the strength of the indicators showed at the weakest point a factor of safety of about 3.

It was originally intended to make a complete test of the plant, including the steam engines, but this was afterward abandoned and nothing was done in testing the steam end save to take indicator cards. The latter was made necessary by the fact that the engines are non-condensing.

The cooling water for the jackets and intercoolers was to be obtained from the city mains, measured in barrels, and returned to the sewer. By this method the use of steam for the circulating pump would be avoided. In all, eight series of cards were to be taken, and it was desired to employ some means for applying the pencil motions simultaneously. For this purpose the electromagnet system was tried, but was found to be unreliable, and a pneumatic system was adopted in its place.

There are three causes tending to diminish the weight of air compressed per cubic foot of piston displacement. These are:

1. Clearance in the low pressure compressor.
2. Leakage past the piston and through the intake valve.
3. Heating of air in passing through the intake valve into the compressor.

The first of these effects merely a reduction of capacity with a compressor using automatic poppet valves, as in this case. If the valves have a positive motion, however, a real loss is occasioned. The reason for this is apparent. When automatic

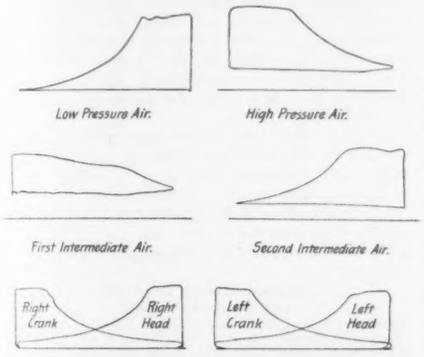


Fig. 2.—Cards from the Four Air and Four Steam Cylinders.

valves are used the air left in the clearance space expands until it reaches the atmospheric pressure, when the intake valve opens, and "free" air is drawn in. The volume of free air compressed per stroke is therefore less than the total piston displacement by an amount equal to the volume of the re-expanded air. If the intake valve is opened mechanically at the end of each stroke, then the unexpelled air rushes out, and the work done upon it is wasted.

Leakage past the piston or valves in the first compressor is a loss of the same nature. Since the law of adiabatic compression is always the same for a given gas, the work of compression depends only upon the initial volume and pressure, and upon the final pressure. It therefore requires just as much work to compress a cylinder full of warm air as to compress a greater weight of colder air occupying the same initial volume. In the former case the loss of temperature by dissipation of heat upon the standing is greater than in the latter. Consequently the heating of intake air represents a real loss of economy as well as a loss of capacity.

In obtaining the volumetric efficiency of a compressor it is easy to eliminate the effect of clearance, but as yet no successful means has been devised for giving the exact temperature of the air at the beginning of compression. To effect this object a considerable amount of work was done, but insufficient time compelled its abandonment. Of the several methods considered, that of a coil of wire having a high co-efficient of resistance, measured by a Hotchkiss galvanometer, seems most promising. The resistance coil may be placed within the compressor directly in the path of the incoming air.

The Test.

As water is fed into the several coolers through independent branch pipes, it was necessary to measure the amount passing through each separately. Five ¾-in. meters were therefore procured from the Thompson Meter Co. through the influence of the American Air Power Company. These were inserted in the sundry pipes beneath the floor, in order that they might not interfere with the discharge.

During a preliminary trial the high pressure indicator cock was found to leak so badly as to seriously threaten the success of a volumetric test. It being clear that a cock of this form could never be made to retain air at 2,500 lbs., the following expedient was resorted to: A hydraulic needle valve was substituted for the indicator cock, and the latter was screwed into the top of it. This was necessary in order to provide a fitting capable of receiving the indicator. The indicator cock was opened and tightened so as to be held immovably in that position. On taking the cards the air was thereafter turned on or shut off by means of the hydraulic valve. Thermometers used in taking water temperatures were inserted in the usual form of thermometer well. Those used for air temperature were bound onto the outside of the pipes with a covering of thick hair felt.

Everything being in readiness, and all leaks in the receiving reservoir having been remedied, the first run was begun at 4.05 p. m., on Wednesday, May 12. During this run the covers of the water boxes surrounding the compressing cylinders were raised, and cooling water was supplied only as fast as it would run out of a 1½-in. discharge pipe.

Three of the four sections composing the receiving battery were compressed into. They were initially at atmospheric pressure. The several readings were taken at intervals of ten minutes. Two persons were able to take the eight indicator cards without difficulty. The working of the pneumatic system of taking simultaneous cards was prompt, reliable, and all that could be desired. No cards were lost through its failure to operate.

Throughout the run all went smoothly, with the exception of the breaking of a reducing wheel on the low pressure side. This was not a serious misfortune, however, as the cards on this side are practically uniform in area, form and characteristics. The wheel was repaired, and no further trouble was experienced. This run lasted until 9.15 p. m., when the pressure in the receiving tank had reached 175 atmospheres.

Before beginning the test careful measurements had been made of the temperature in the receiving battery. After standing over night these temperatures were taken again. Knowing the volume of the reservoir, sufficient data were thus obtained for computing the exact weight of air compressed.

With the double purpose of determining the volumetric efficiency throughout the higher range of pressure, and of ascertaining the effect of increased flow of cooling water, a second run was begun at 11.50 a. m., on Thursday, May 13th. In this run the initial pressure was 120 atmospheres, and the cover of the high pressure side being fastened down, water was forced through under pressure. At 1.20 p. m. the pressure in the receiver had reached 170 atmospheres, and the run was stopped. The barometric pressure on both days was obtained at the office of the weather bureau.

In both runs assistance in taking readings was rendered by Mr. A. H. Cooke, Cornell '98, and by Messrs. Christy, Chapin, and Kidde, Stevens Institute '97.

The Cards.

The indicator card is a reliable index of all that is taking place within a thermodynamic or dynamo-thermal machine. In the present case it possesses unusual interest, as cards taken at such high pressure are comparatively rare.

To be a faithful record of pressure variations, the movements of the drum must be accurately proportional to the displacement of the piston within the cylinder. Great care was therefore used in setting up the motion transmitting line. The reducing wheels were so placed that the cord connecting to the crossheads should be always parallel to the center line of the piston rod. The indicators were adjusted so that the cords leading to them should always have a fixed direction. Excepting where the line necessarily passed over pulleys, fine piano wire was used.

An inspection of the steam cards reveals nothing unusual. They are fairly typical of single wrist-plate Corliss engines. There is, perhaps, too little compression, and the release might be earlier. Cut-off is quite well defined, and there is not a great amount of wire drawing.

The card from the low pressure compressor could scarcely be improved upon. Compression is smooth and regular, and the absence of re-expansion is phenomenal. The valves seem to operate promptly, particularly the piston inlet valve, which is employed in this compressor, and of which the Ingersoll-Sergeant Drill Co. are the originators. This form of valve is also used in the inlet to the second intermediate stage. A noticeable characteristic of these two cards is the sharpness with which compression begins. In this respect comparison with the second intermediate and high pressure cards, in which drop valves are used, is very favorable to the piston inlet.

The discharge valves for the low pressure stage

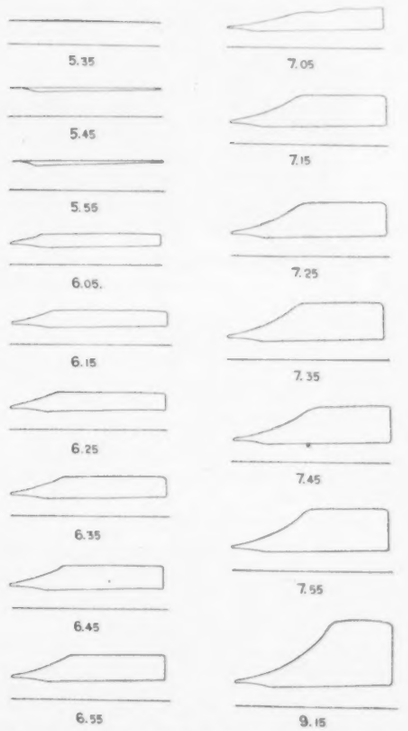


Fig. 3.—Cards from the High Pressure Air Cylinder at Different Times.

are closed by springs. As there is no surface upon which back pressure can act, the work in this compressor is practically constant. The card from the first intermediate stage is very peculiar and tells an interesting story. It will be noticed that there is a "second impulse" to the compression. Obviously the first break in the curve cannot be the beginning of discharge, since the pressure at this point is lower than that in the receiver. Neither is it probable that the trouble is due to leakage past the piston, for in that case there is no apparent explanation for the lack of continuity in the curve. The remaining inference is as follows: At the beginning of the compression stroke the valve sticks, and does not close tightly. As the piston advances the air leaks back into the receiver until the pressure has become sufficiently high to force the valve down, when the compression begins again, and this is continued to the point at which the real discharge commences. This peculiarity may also be noticed in the high pressure card taken at 7.05 p. m.—a significant fact, as valves of similar construction are used in the two compressors. At this time this cylinder had not begun to approach full load.

The last two series of cards are interesting chiefly from the high pressures involved. In the intake of the second intermediate card the characteristics of cross-compound engines may be noticed, while the characteristics of tandem compound engines are exhibited by the high pressure card. The peculiarity is not sufficiently pronounced in either, however, to indicate too small a receiver volume. The discharge lines in these cards are typical of automatic valves.

The Mechanical Efficiency.

In the operation of regulating speed, the governor is continually changing the point of cut-off. Consequently there are moments when the energy stored in the fly-wheel is drawn upon to make up a deficiency in the power supplied by the engines. For this reason the mechanical efficiency shown by the cards is constantly fluctuating. Moreover, as friction is nearly constant, it is a quantity of much greater relative magnitude when the machine is doing light work than at full load. Hence, again, there is a continual increase in the mechanical efficiency as full load is approached. The accompanying curve shows this very nicely. The general trend of this curve is upward, but at a constantly diminishing angle. It is undoubtedly an arc of an hyperbola with the 100% line for an asymptote. The average mechanical efficiency is found to be 90.2%, which is very creditable for new machinery.

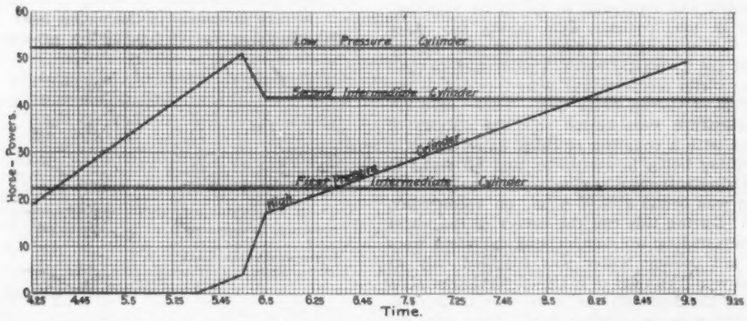


FIG. 4.—POWER DEVELOPED IN THE FOUR AIR CYLINDERS DURING COMPRESSION FROM 1 TO 170 ATMOSPHERES.

The Combined Card.

As drawn by the indicator, the card is a pressure-volume diagram. Taken by itself, it shows merely relations. But when the scales of ordinates and abscisse are known, it gives actual measurements of volume, pressure and work.

Comparison of characteristics may be made between any two cards; but in order to compare magnitudes they must be reduced to the same scales. For example, take the cards from the low and high pressure cylinders. They are both of the same length, but one represents the piston displacement of 7.241 cu. ft., while the other represents only .1795 cu. ft. The former shows at its highest point a pressure of 75 lbs.; the latter 2,500 lbs. per sq. in.

A set of diagrams taken at the end of the first run has been redrawn to the same scale of both ordinates and abscissae. This combined card, so-called, shows at a glance the relations of the several cards to one another, and the part each cylinder plays in the final compression.

Starting from the same point as the actual, two theoretical compression curves have been drawn. The adiabatic line shows the course the compression would have followed had no heat passed from the air. Its equation is, $P V^{1.405} = \text{Constant}$.

The isothermal is defined by the equation, $P V = \text{Constant}$.

Adiabatics and isothermals have also been drawn for each individual card. An inspection of these discloses a number of important facts, namely: First, that the water jackets surrounding the cylinders are not effective in cooling the air; second, that there is certainly no leakage from the third or low intermediate cylinders; third, that leakage from the high pressure cylinder is improbable; fourth, that there is a very considerable leakage from the first intermediate stage, either past the piston or through the inlet valve. These conclusions are drawn from the fact that the compressions are practically adiabatic, with the exception of the two stages last mentioned.

Now the construction of the compressor is such that air finding its way past pistons or inlet valves in either of the last two stages would simply reenter the second intermediate receiver and not leave the system. Only by leaking past the pistons in the first two cylinders, or passing through some joint in the connections, can air escape to the atmosphere. A leak of the former nature would quickly be detected. The only channel remaining then is that of the first intermediate stage. The opinion has already been expressed that the peculiarity in this card is due to the leakage through the inlet valve.

It is not surprising that the water boxes show so little effect on the compression line, as it is well known that air is an excellent non-conductor of heat, and the distance to which the cooling effect penetrates is therefore very small. In the intercoolers the air is made to pass over the cooling surface in very thin layers. Their effectiveness, as shown by the combined card, is very marked.

Efficiency of Compression.

This is commonly understood to mean the ratio of the theoretical work required to compress air isothermally to the actual work done in compressing to the same pressure from the same initial pressure and volume. In computing the actual work, it should be remembered that after the discharge valve opens the air undergoing compression is not merely that within the cylinder, but the combined masses within the cylinder, receiving tank, and pipe connections.

If leakage of air occurs, the indicated work will be lessened, and the efficiency of compression, as defined above, correspondingly raised. The result is, however, not correct, for in this case, instead of the original weight of air, we really have a smaller weight, which maintains the same pressure for a given volume only by reason of being heated a correspondingly greater amount.

Even though a compression line obtained in this way should coincide with the isothermal, there will still be a loss of work by dissipation of heat upon standing.

Volumetric Efficiency.

The conditions under which this test was made were very favorable for getting the volumetric efficiency with a high degree of accuracy. Air was compressed into a closed tank, and by knowing the initial pressure and temperature, and the final temperature and pressure, together with the volume of the tank and connections, the weight of the air compressed into it between the two ranges was readily attainable. The weight of free air taken in during the run is that due to the low pressure piston displacement under the existing conditions of temperature and pressure. As before explained, the pressure at the beginning of compression could not be obtained, so that it was assumed that the air underwent a rise of temperature of 9° in passing over the intake valves.

A compressor of this kind would be expected to give a slightly higher volumetric efficiency when working through low ranges of pressure than through high ones. This was found to be the case, for in the first run the pressure ranged from one atmosphere to 170 atmospheres; the latter run gave an efficiency 1% lower than the former.

The Cooling System.

The cooling system of this compressor is very complete, and does remarkably well the work laid out for it to do. The cooling in the cylinders, especially in the low pressure cylinder, is not so decided as it is in the intercoolers and aftercooler. There is a reason for this, however, and it is due to air being a very poor conductor of heat; in the low pressure cylinder, at the beginning of compression, there is a volume of over 7 cu. ft. of air, and the cooling surface is relatively so small that cooling action takes place on only a thin layer of air next to the cylinder walls, the result being that the compression curve does not leave the adiabatic a sufficient amount to be noticeable. As the compression increases it is found that the decrease of volume of air in the cylinder is more rapid than the relative decrease of cooling surface, and in the last stage of compression the curve falls a very perceptible amount inside of the adiabatic line.

The work of the intercoolers is very pronounced, as may be seen from the data obtained, and curves plotted. It is to be regretted that temperatures of the air before entering and after leaving the second intermediate cylinder, and before the last compression, could not be obtained, but there is good reason to believe that the second and third coolers did good work, judging by the temperature at the end of the fourth compression.

The aftercooler makes the most decided record for reduction of the temperature of the air. The accompanying curves illustrate this better than a prolonged discussion could do. It is very interesting to note that the average temperature of the air leaving the aftercooler is a fraction of a degree below that of the entering air. This, more than anything else, speaks well for the cooling efficiency of the cooling system.

Results show that the average temperature of the air in the receiving tanks is a few degrees above the temperature of the air leaving the aftercooler. This, at first thought, tends to cause doubt in the mind of the reader, but it is accounted for by the compression that takes place in the receiving tank as the air is discharged from the compressor.

Summary of Data and Results.

Low Pressure Cylinder.

Diameter, ins.	21.25
Length of stroke, ins.	36.
Diameter of piston rod, ins.	3.
Displacement per stroke of piston, cu. ft.	7.241
Volume of clearance, cu. ft.	.0429
Volume of clearance, %	.59

First Intermediate Cylinder.

Diameter of piston, ins.	9.
Diameter of piston-rod, ins.	0.
Piston displacement per stroke, cu. ft.	1.325
Volume of clearance, cu. ft.	.0144
Volume of clearance, %	.108

Second Intermediate Cylinder.

Diameter of piston, ins.	7.
Diameter of piston rod, ins.	0.
Piston displacement, cu. ft.	.571
Volume of clearance, cu. ft.	.0034
Volume of clearance, %	.59

High Pressure Cylinder.

Diameter of piston, ins.	3.1-32
Diameter of piston rod, ins.	0.
Piston displacement, cu. ft.	.1795
Volume of clearance, cu. ft.	.0042
Volume of clearance, %	2.34
Diameter of fly-wheel, ft.	16.
Average revolutions per minute	58.8

Volume of Coolers.

First intercooler, cu. ft.	9.
Second intercooler, cu. ft.	1.8
Third intercooler, cu. ft.	.7
Aftercooler, cu. ft.	1.6

Cooling Surfaces.

First intermediate, sq. ft.	112.
Second intercooler, sq. ft.	60.
Third intercooler, sq. ft.	35.
Aftercooler, sq. ft.	45.
Low-pressure cylinder, sq. ft.	21.
First intermediate cylinder, sq. ft.	8.
Second intermediate cylinder, sq. ft.	7.
High-pressure cylinder, sq. ft.	2.5
Total	290.5
Capacity per stroke, lbs.	0.549
Capacity of free air per min., cu. ft.	425.7
Weight of air at 2,497 lbs. per sq. in. comp. per D. HP.	0.186
Weight of water used in cooling 1 lb. of air.	20.2

Distribution of Water During Run, in Pounds.

First box	21.229
First cooler	45.352
Second box	43.717
Second cooler	23.541
Aftercooler	21.480
Total	155.321

	Degrees.
Temperature of inlet air	76.8
Temperature of air at beginning of comp., assumed	85.
Temperature of air leaving aftercooler	76.5
Average rise of temperature in water, first box	12.
Ditto, first cooler	14.
Ditto, second cooler	10.4

Heat Accounts, B. T. U.

First box	238,738
First cooler	627,970
Second box	785,740
Second cooler	220,911
Aftercooler	197,238
Heat in receiving tank	25,257
Radiation	969,241
Total	3,061,095
Heat due to continuous adiabatic compression	3,061,095.
Work per pound of air, continuous adiabatic compression to 2,400 lbs.	244,936.
Ditto, isothermal	150,230.
Ditto, actual	168,999.
Work per lb. of air by re-expansion	62,418.
Mechanical efficiency, %	90.4
Efficiency of compression, %	88.9
Volumetric efficiency (entire range), %	89.34
Volumetric efficiency (high range), %	88.45

Conclusions.

Considering the brief time during which this compressor has been in operation, the mechanical efficiency is excellent. The efficiency of compression is exceptionally good, and the volumetric efficiency demonstrates beyond a doubt that leakage presents no insurmountable difficulty to the design of high pressure machinery.

It has been shown that the leakage, such as it is, must take place from the first intermediate stage, in which the pressure does not exceed 160 lbs. The difficulty, therefore, does not arise from the high pressures dealt with, and there is no reason why it should not be easily remedied. Remembering that this is the first of the new type of compressor, it does not seem surprising that a defect of this kind should be found.

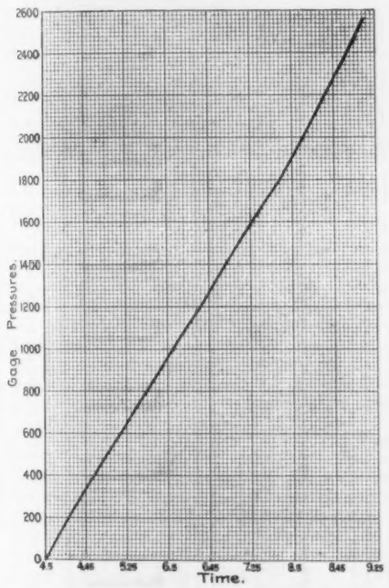


Fig. 5.—Curve Showing Rise of Pressure in the Receiving Tank.

In conclusion, it may be said that to the writer the future of this compressor and the class which it represents seems very promising.

Mean Effective Pressures from Indicator Cards.

Time.	Revolutions, per min.	Steam cards.—Left crank.	Steam cards.—Left head.	Steam cards.—Right crank.	Steam cards.—Right head.	Air cards—H.-p. cylinder.	Air cards—2d cylinder.	Air cards—3d cylinder.	Air cards—H.-p. cylinder.
4:25	58.1	21.56	21.34	21.58	21.12	29.08	60.61	134.9	0
5:25	58.8	20.61	26.11	27.18	30.00	29.16	68.11	286.3	0
6:25	58.6	.....	.....	29.30	31.67	.....	.....	275.7	453.1
7:25	58.6	.....	.....	30.91	31.33	.....	.....	284.6	709.4
8:25	58.9	33.00	32.66	33.44	32.00	32.10	65.45	286.6	919.3
9:15	58.4	33.91	34.79	34.62	37.67	31.18	68.04	294.2	1095.7
Indicated Horse-power.									
4:25	58.1	28.29	27.60	28.32	27.31	53.39	20.36	19.55	0
5:25	58.8	27.37	34.18	36.10	39.26	54.19	23.16	42.00	0
6:26	58.6	.....	.....	38.79	41.31	.....	.....	40.30	20.80
7:25	58.6	.....	.....	40.91	40.86	.....	.....	41.61	32.57
8:25	58.9	43.91	42.81	44.49	41.95	53.24	22.29	42.12	42.40
9:15	58.4	44.90	45.22	45.67	48.97	53.18	22.30	42.88	50.13

Condensed Abstract of the Records of Observations.

Time.	Revolutions.	Pressures.—Receiving tank, atmospheres.	Cooler—1st, lbs.	Cooler—2d, lbs.	Cooler—3d, lbs.	Air Temperatures.—Intake.	Enterg cooler.—1st	Leav'g cooler.—1st	Leaving compr.—2d	Leaving compr.—4th	After cooler.	Receiving tank.—Top.	Receiving tank.—Bot'm.
4:15	466	6.0	55	120	320	73	132	84	140	80	74	..	..
5:15	3,923	35.0	59	125	640	76	187	94	154	99	75	..	70.7
6:15	7,451	68.5	57.5	123	650	77	184	95	155	127	75.5	86	75
7:15	10,974	102.2	59	123	650	77	184	96	157	162	77	92	77
8:15	13,909	138.0	59	124	660	78	188	98	159	192	77.8	97	78.5
9:15	18,000	175.0	60	126	665	78.5	194	98	162	214	79	101	80

Heat Taken up by Cooler (in Ten Minute Periods).

Time.	Temp. entering water.	1st box.—Temp. water.	1st box.—B.T.U.	1st cooler—Temp. water.	1st cooler—B.T.U.	2d box.—Temp. water.	2d box.—B.T.U.	2d cooler.—Temp. water.	2d cooler.—B.T.U.	Aftercooler.—Temp. water.	Aftercooler.—B.T.U.
4:15—4:25	73	81	5,340	88	17,445	82	8,833	79.5	4,674	73.5	284.7
5:15—5:25	73	84	9,102	88	19,575	88	18,247	84	6,809	75	1,302
6:15—6:25	74	86	8,616	86	20,707	90.5	27,890	83	7,258	80	5,190
7:15—7:25	75	87	7,650	88	19,798	92.5	26,010	85	7,009	85.5	8,789
8:15—8:25	75	89	8,105	90	21,180	106.5	43,360	86.5	7,515	90	11,701
9:05—9:15	77	90	7,920	92	21,649	90	29,780	88	7,438	95	13,340

About ten days after the tests reported in the above thesis were made, a second set of tests on the same compressor was made by Messrs. W. W. Chapin, R. C. Christy and Walter Kidde, of the class of 1897 Stevens Institute of Technology, and these gentlemen also prepared a graduating thesis describing their tests. The following is a condensed summary of the results which they obtained in three tests, one of 400 minutes duration, in which the pressure in the receiver rose from 0 to 170 atmospheres; one of 90 minutes, with the pressure rising from 135 to 170 atmospheres; and one of 130 minutes, with the pressure maintained constant at 170 atmospheres:

	Tests—I.	II.	III.
Air Temperatures (deg. F.)			
Intake	76.2	71.8	74.1
Entering first receiver	161.8	162.2	176.4
Leaving first receiver	94.5	94.2	90.1
Leaving second cylinder	147.6	133.7	142.3
Entering second receiver	149.4	131.2	143.2
Leaving fourth cylinder	141.2	204.0	230.8
Leaving aftercooler	78.8	72.2	76.1
In storage tubes	77.7	76.6	78.4
Length of test in minutes	400	90	130
Av. revolutions per minute	58.6	58.3	58.3
Average Horse-Power of Steam Cylinders.			
Right hand, head end	37.13	45.36	45.43
Right hand, crank end	37.11	43.46	44.30
Left hand, head end	44.03	46.96	48.75
Left hand, crank end	35.48	41.90	42.57
Total	153.75	177.68	181.05
Horse-Power of Air Cylinders.			
Low pressure	57.80	58.46	59.05
First intermediate	21.37	21.01	21.20
Second intermediate	44.01	47.76	48.01
High pressure	19.71	40.82	45.35
Total	142.89	168.05	173.61
Mechanical Efficiency.			
Av., each set of 8 cards, %	91.75	94.7	95.65
Friction, %	8.25	5.3	4.35
Storage pressure, lbs. per sq.in.	0 to 170	135 to 170	170
Temperature of storage, deg.	77.7	76.6	78.4
Barometer in inches	30.19	30.17	30.17
Temperature of intake air	76.2	71.8	74.1

	Test I.	Test II.
Air in storage, beginning test, lbs.	64.09	7,996.05
Air in storage at end of test, lbs.	10,138.6	10,453.27
Displacement,* per stroke, cu. ft.	7.266	7.266
Total number of strokes	23,418	5,223

*Low pressure air piston.

Test I.—Calculating for three periods of time, 50, 90 and 400 minutes, the volume of free dry air compressed per minute, at intake temperature and barometric pressure was:

From 144.9 to 168.1 atmos. (gage)	365.75 cu. ft.
" 127.4 " 168.1 " "	356.13 "
" 0 " 168.1 " "	359.3 "
Average	353.72 cu. ft.

The capacity efficiency for the three periods was respectively 95.64%, 93.81%, and 88.94%.

Test II.—For two periods of 50 and 90 minutes, the volume of free dry air compressed per minute was:

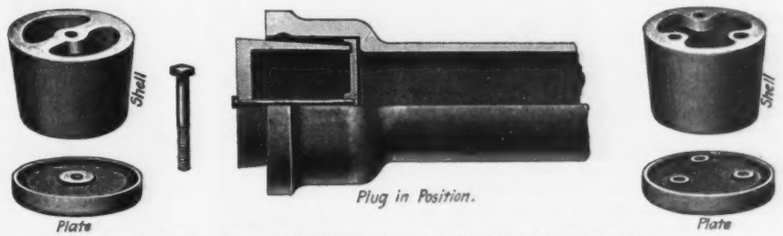
From 146 to 170.3 atmos. (gage)	377.8 cu. ft.
" 127 " 170.3 " "	367.67 "
Average	372.73 cu. ft.

The capacity efficiency for the two periods was respectively 90.37% and 97.35%.

The average efficiency of the two tests was 95.24%.

A RECOVERABLE PLUG FOR CAST-IRON WATER MAINS.

The ordinary cast-iron plug used to stop dead ends and specials in the distribution system of a water or gas plant can only be removed by breaking it, thus rendering its further use impossible. Mr. D. A. Streeter, of Waterbury, Conn., is now making a plug which is so designed that it can readily be removed from the pipe and used over and over again. The plug is shown by the accompanying illustration. It is in two parts, bolted together with a single bolt for small sizes, and with three or more bolts for sizes about 6 ins.



A RECOVERABLE CAST IRON PLUG FOR WATER OR GAS MAINS.

To put in one of these plugs the plate and shell are bolted together, a little fire clay being placed between the two surfaces before joining them. A hot lead joint is then made between the two parts, and fire clay is rubbed over it, this material being used here to prevent a junction between the two lead joints. The plug is then inserted in the bell or socket, the joint yarned and then poured with lead and calked.

To remove a plug the bolt or bolts are unscrewed and the shell is knocked loose with a hard wood block and hammer and is then removed. The lead is then cut with a cold chisel; the cut edges are bent in and the ring is removed. The bolt is then screwed in and the plate is removed. The lead packing ring between the shell and plate can be used several times.

The spigot end of the pipe can also be plugged if desired, using a plug of the proper size. Clamps for this purpose are furnished by Mr. Streeter, as are also forcing bolts for removing plugs from very deep bells.

It is claimed that this plug can be inserted as quickly as an ordinary plug, and can be removed in much less time, besides saving the dulling or breaking of cutting tools. Mr. Streeter states that the plug is now used in connection with the waterworks at Waterbury, Conn., Holyoke, Taunton and Middleboro, Mass., and that he has applied for a patent on the device.

SOME NEW LAKE ERIE COAL HANDLING PLANTS.

The very serious loss from breakage in transferring coal from cars to boats at our Great Lake ports has led to a pretty careful study of conveying machinery designed to avoid vertical drops and all crushing action as much as possible. In our issue of Feb. 11, 1897, we described quite fully the method and machinery for handling coal at a large wholesale city coal yard, located at Chicago, Ill. This plant was designed to unload coal from boats coming from Cleveland and other Lake Erie ports, and to sort, distribute and store it ready for delivery to city retail coal dealers. The accompanying illustrations show quite clearly the na-

ture of some of the more improved plants located at the opposite end or beginning of the lake water routes, and when studied in connection with the earlier article, cover the whole process of handling coal from the railways to the water lines and from the water lines to the storehouses of the wholesale dealers in the Great Lake cities.

The plant illustrated here is one of five built during the past year or two at large Lake Erie ports, to which the coal is brought by rail from the Pennsylvania and Ohio coal fields. Two of these plants are located at Toledo, O., one at Ashtabula Harbor, O., one at Huron, O., and one at Cleveland, O. These plants are all alike except in some minor details, and all were built by the Brown Hoisting & Conveying Machine Co., of Cleveland, O., after the designs of Mr. Alex. E. Brown. Fig. 1 is a general plan, with elevations and sections, showing the arrangement and operation of the various parts of the plant; Fig. 2 is a view showing the car clamped in position for dumping, with the rows of buckets into which it empties ranged in front, and Fig. 3 shows the car dumped and about to return to its first position.

The railway companies either operate the machines themselves, or arrange to deliver the loaded cars to the plant. The cars are run onto the elevated tracks at A, Fig. 1, and then descend by gravity to B, one at a time, as wanted. From this point the disappearing carriage, which consists of a small counterweighted car, C, with a bumper at one end, and propelled by means of a cable, pushes the car into the tipple D. By comparing the reference letters on the various drawings of Fig. 1 the nature of these preliminary operations will be clear.

The car is securely held in the tipple frame by a hydraulic clamping device which takes hold of the car frame on both sides and holds it immovably in place. These clamps are designed with ample adjustment to allow for the various widths and heights of different cars. Fig. 2, which shows the car clamped in the tipple, also shows six pockets fastened to the tipple above the car and in an inverted position, that is, with their bottoms uppermost. As the tipple turns over to the position shown by Fig. 3, the coal slides out of the car body into these six pockets, while the pockets descend inside of the six buckets placed on the car in front. As soon as the pockets are fully inside the buckets their wedge-shaped sides and bottoms unlock automatically along the apex of the wedge, so to speak, and swing back so that as the tipple returns to its normal position the pockets are drawn out of the buckets, leaving the coal, which it will be seen has had no vertical fall. As the pockets clear the buckets their bottoms automatically close and lock, and the tipple is ready for the next car, which, as it is pushed into the tipple by the disappearing carriage, pushes the empty car out at the other end, from which it runs away by gravity, and is automatically switched onto a side track.

The foregoing describes the main operations of the tipple only. A man is placed on the loaded car as it enters the tipple, who sees that the car is properly placed, and that the hydraulic clamps are properly adjusted, and also attends to the fastening and unfastening of a pair of end doors or guards, which are constructed of iron or wood and attached by means of quick-acting screw clamps to the top of each end of the car before turning it over so as to prevent the spilling of any of the coal over the car ends. These guards are suspended by a chain and counterweight from the stationary framework of the tipple and are within convenient reach.

Altogether there are eighteen buckets to receive the coal from the coal cars. These buckets are carried by three bucket cars, six buckets to a car, which are operated by a cable and run on a track parallel with edge of the dock. Each bucket has a capacity of six tons, and the six buckets on a car have an aggregate capacity of 36 tons, or a full carload of coal. The bucket cars are placed in the proper position opposite the tipple by means of the pulling rope, there being a pointer which automatically indicates this position to the operator.

The work of putting the coal from the buckets into the boat is accomplished by two traveling cranes, shown at M and N, Fig. 1. These cranes travel parallel with the edge of the dock at the

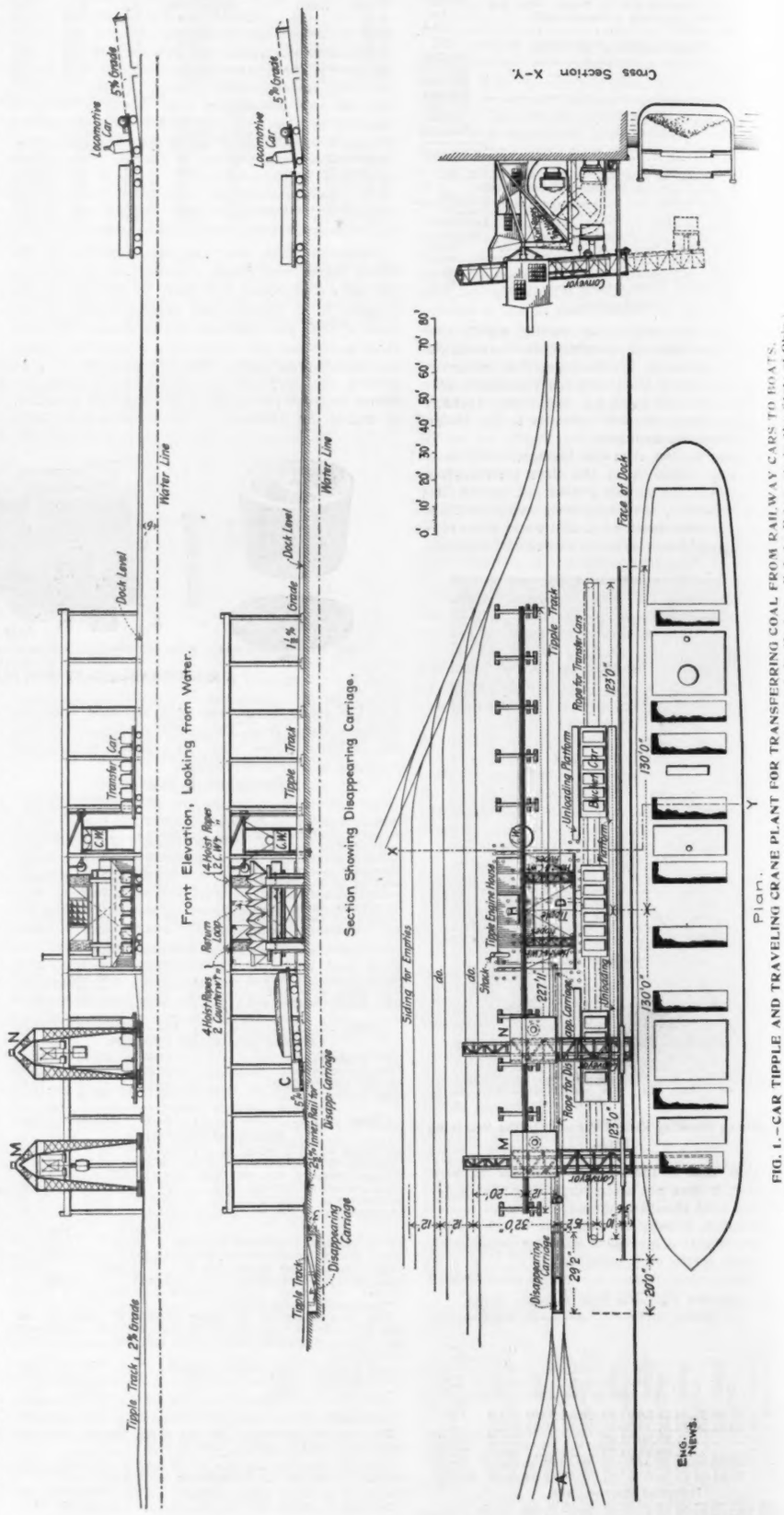


FIG. 1.—CAR TIPPLE AND TRAVELING CRANE PLANT FOR TRANSFERRING COAL FROM RAILWAY CARS TO BOATS.
(Plants of this type have been built at Cleveland, Toledo, Huron and Ashtabula Harbor, all Lake Erie ports in the State of Ohio.)
The Brown Hoisting and Conveying Machine Co., Cleveland, O., Designers and Builders.

will of the operator, each crane having its own boiler, engine and other operating machinery complete. The maximum speed of travel is from 500 ft. to 600 ft. per minute. As will be seen from the views, Figs. 2 and 3, the back ends of the cranes travel on an elevated track, while the front end, consisting of a strongly built shear leg travels on a rail laid along the front of the dock. The cranes can pass over the tipple structure freely.

Each crane, as will be seen from the illustrations, has an extensible arm or boom, which can be hauled in to clear the edge of the dock or thrust out any distance demanded by the hatches of the vessel. A peculiarly-designed block provided with two hooks at each end is suspended from a carriage traveling lengthwise of the boom. The block hooks fit into four eyes on the bucket, two at each end. The operator, by lifting on one set of hooks, raises the bucket from the car and lowers it into the hatch of the vessel, until it is within a few inches of the surface of the coal, when he lifts on the other pair of hooks, which unlock the bottom of the bucket and allow the shell to be pulled away, leaving the coal. It will be noticed again here that the coal has no fall or drop to cause its breakage. As soon as the bucket is empty the operator lifts on the first set of hooks, which closes the bucket, after which it is placed back on the bucket car and unhooked. Two men who stand on platforms running along the sides of the bucket car tracks do the hooking and unhooking. Each crane has an operator and fireman.

It will be seen from what has been said that the cranes and tipple are operated by separate men. All the operations of the tipple, including running the disappearing carriage, operating the hydraulic clamps, turning the tipple, and moving the bucket cars, are accomplished by one man located in the tipple operator's house H, by means of hand levers and foot brakes. Directly underneath the operator's house are located the tipple engines, boilers and other machinery, all of which are looked after by one man.

The above description studied in connection with the drawings of Fig. 1, which gives all the more important dimensions, makes the construction and operation of these very novel coal handling plants quite clear. It will noticed that ten men, including a foreman, are required to operate the plant. If it is impracticable to run the empty cars out of the tipple by gravity, a special locomotive car shown by the illustrations is used, and the operating force is increased by one man. With regard to the capacity of the plant and the cost of operating it the builders send us the following statement:

> The cost of operating a complete plant, including the wages of the men, necessary fuel, oil, waste, etc., and allowing a fair amount for depreciation of plant, does not exceed $40 per day. The plant is guaranteed to load from cars holding not less than 24 tons each, 3,000 tons in ten hours, but actual practice has shown that with the ordinary run of gondola and hopper-bottom cars, the capacity will easily reach 4,000 tons, which amounts to loading a boat with coal, for about 1 ct. per ton. The tipple itself, however, is capable of easily handling from 8,000 to 9,000 tons in ten hours, so that if at any time it is found necessary or advisable to increase the capacity of the plant it can be done at a comparatively small expense, by adding one or two more traveling cranes and additional buckets and bucket cars.

It will be noticed that these last figures of tipple capacity mean that a carload of coal is handled every two minutes during the ten hours. In making their claim of 900 tons per hour, therefore, it is evident that the builders have not allowed for delays in getting the cars to the tipple, and have in mind almost perfect theoretical operation and management.

Considering this plant in a broad way, perhaps the most impressive feature is the magnitude of the task of picking up and emptying a loaded car of coal as deftly and easily as a man would handle a coal hod. A hopper bottom coal car of 30 tons capacity will weigh 12 or 13 tons, which makes the load lifted at least 42 or 43 tons. The fact that the coal nowhere has a vertical drop during the entire process of transferring it from the cars to the boat has already been mentioned, and engineers will not fail to note the simplicity with which this has been attained, while at the same time the machine has made an enviable record for its rapid and economical working.

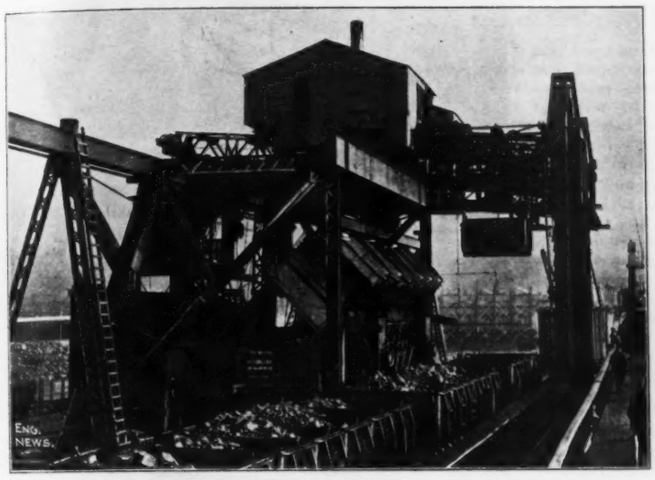


FIG. 2.—VIEW SHOWING CAR CLAMPED IN TIPPLE READY FOR DUMPING.

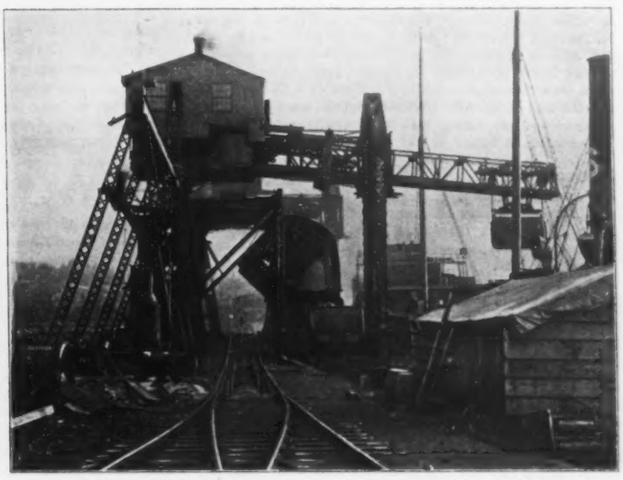


FIG. 3.—VIEW SHOWING CAR DUMPED AND READY TO RETURN TO THE POSITION SHOWN BY FIG. 2.

THE FILTRATION OF WATER.

A paper on the filtration of water, by Mr. Edmund B. Weston, M. Am. Soc. C. E., of Providence, R. I., was read at the convention of mayors and councilmen at Columbus, O., last week. The paper was a general review of the methods employed and results obtained or possible in the best examples of slow sand and mechanical filtration. As the paper was prepared for reading before a body of laymen, most of it consisted of matter quite familiar to those who have studied water purification. Some of Mr. Weston's estimates and conclusions do not come within the above category, and will be given briefly.*

The cost of sand filtration at an average rate of 2,000,000, and a maximum rate of 2,500,000 gallons per day, under different conditions, is given by Mr. Weston as follows, the figures being supplemented below by a few words of explanation:

Filter-Beds Covered with Masonry Vaulting.

Cost per acre of filter-bed	$70,000.00
Cost of construction per 1,000,000 gallons capacity per 24 hours	35,000.00
Total cost of filtering 1,000,000 gallons, including expense of operating, interest, deterioration, etc.	7.57

Filter-Beds Covered with a Wooden Roof.

Cost per acre of filter-bed	43,813.00
Cost of construction per 1,000,000 gallons capacity per 24 hours	21,906.00
Total cost of filtering 1,000,000 gallons, as above	6.85

Filter-Beds Not Covered.

Cost per acre of filter-bed	$38,829.00
Cost of construction per 1,000,000 gallons capacity per 24 hours	19,415.00
Total cost of filtering 1,000,000 gallons, as above	6.48

Filter-Beds Not Covered.

Cost per acre of filter-bed	$31,063.00
Cost of construction per 1,000,000 gallons capacity per 24 hours	15,532.00
Total cost of filtering 1,000,000 gallons, as above.	5.09

The first three estimates are intended for filter-plants that could be located where the mean temperature of the coldest month of the year is below the freezing point. The third estimate takes into consideration a reserve area to compensate for ice forming over the filter-beds. The fourth and last estimate is intended for a filter-plant that could be located where the mean temperature of the coldest month of the year is above the freezing point. None of the estimates include the cost of sedimentation basins.

In considering mechanical filters Mr. Weston takes, as the best type, an open gravity filter, provided with a settling basin, and making use of sulphate of alumina as a coagulant. He outlines the principal features of a first-class mechanical filter plant with a daily capacity of 20,000,000 gallons, as follows:

> A filter house 250 ft. long and 64 ft. wide, containing a flume about 8 ft. wide running lengthwise through its center, for receiving and taking away the filtered water; 20 filters, each of 1,000,000 gallons capacity, ten of which are located on each side of the flume; the supply and wash pipes for bringing the water to the filters; the drain pipes for removing the dirty water during the process of washing the filters; the steam pipes for [illegible] the filter-beds and heating the building; and all other necessary pipes and appurtenances. An engine and boiler house 60 ft. square, containing the boilers for supplying the steam; a pump for washing the filters; an engine for driving the shafts in the filter-house, which work by the aid of belting and mechanical rakes in the filters when they are being washed; an automatic chemical pump for adding the sulphate of alumina coagulent to the water being supplied to the filters; the tanks for mixing and holding the coagulent; the air-pump for aiding in the mixing of the coagulent; and the electric lighting and signal apparatus. And a shed or small building for storing coal and sulphate of alumina in bulk.
>
> The most efficient filter-plants that have recently been constructed make use of sedimentation tanks as adjuncts to the filters, through which the water passes before it enters the filters. These tanks are sometimes built independent of the filters, and sometimes they are located directly under the filters, the lower part of the cylindical shell containing the filter-bed, being arranged and utilized for the purpose. When sedimentation tanks are used, the sulphate of alumina coagulent is added to the water as it flows to the tanks.

The estimated cost of a mechanical filter plant designed along the above lines, and filtering at the rate of 128,000,000 gallons per acre per day, Mr. Weston gives as follows, to which we append his comments on the estimate and his conclusions regarding the relative merits of slow sand and mechanical filtration.

Cost of construction per 1,000,000 gallons capacity per 24 hours	$13,500.00
Total cost of filtering 1,000,000 gallons, including the expense of operating, cost of sulphate of alumina at the rate of one grain per gallon @ $1.75 per 100 lbs., interest, deterioration, etc..	6.41

The above estimate is intended for filter-plant that could be located anywhere without regard to the mean temperature of the coldest month of the year. For a climate where the mean temperature of the coldest month of the year is above the freezing, the cost would be somewhat less. The writer considered one grain of sulphate

*In our issue of April 16, 1896, there appeared an abstract of a valuable report by Mr. Weston, on experiments made under his direction on the mechanical filtration of water.

of alumina per gallon in the estimate, as it may be considered as a fair general average of the quantity that would be required for a large number of differently constituted waters; some waters require less and some more; six-tenths of a grain per gallon was the average amount applied during the Providence experiments.

Several large and efficient filter-plants that have been constructed within the last two years, did not exceed a cost of construction of $10,000 per 1,000,000 gallons capacity per 24 hours. The total cost of filtering 1,000,000 gallons, taking into account these figures instead of the $13,500 as given above, would be $5.73.

It will be seen by comparing the estimates of cost which are given in this paper, that the cost of construction per 1,000,000 gallons capacity per 24 hours of an American system (mechanical—Ed.) of filtration plant, as well as the cost of filtering 1,000,000 gallons, is less than that of a sand filtration plant.

A comparison of the third estimate of the cost of a sand filtration plant (which is the lowest of the first three estimates, and, therefore, may be considered conservative) with the estimate of the cost of an American system of filtration plant; namely, $19,415.00 and the $6.48 for the former; and $13,500.00 and $6.41 for the latter; shows that the cost of construction per 1,000,000 gallons capacity per 24 hours of a sand filtration plant is about 44% more than that of an American system of filtration plant, and the cost of filtering 1,000,000 gallons, about 1% more.

Experience has shown that the percentage of color removed is much larger by the American system of filtration than by sand filtration. The percentage of removal of albuminoid ammonia has been shown to be larger by the American system of filtration than by sand filtration. The percentage of removal of the applied Bacillus Prodigiosus, which represents typhoid fever germs, has been shown by experimental filters to be about the same for both systems.

As can be seen by the percentages given in this paper, the average percentage of removal of water bacteria of the Lawrence City filter during three years, and that of an American system of filtration plant during two months is practically the same. The writer is of the opinion, however, that it is quite possible to build sand filters in this country which would be as efficient as the best European sand filters, and, although it may be quite as possible that American system of filtration plants can be built which would be equally as efficient, the experience in regard to building and operating first class plants of the latter system has not yet covered a sufficient length of time to enable the writer to express a positive opinion in this respect. He will, therefore, assume that the best European experience tends to show that a sand filter is 1½% more efficient in the removal of water bacteria than the American system of filtration. If this assumption is correct, does the extra cost of a sand filtration plant compensate for its 1½% increase of efficiency in the removal of water bacteria? The writer is of the opinion that, possibly, in some cases it might; but in many cases that it would not.

For instance; a sand filter plant having a capacity of 10,000,000 gallons per 24 hours, considering, as given above, an increase in the cost of construction of about 44%, and an increase in the expense of operating, etc., of about 1%, would cost $59,000 more than an American system of filtration plant of the same capacity, and the expense of operating per annum, etc., would be about $256 more. It should be remembered, as has previously been stated, that the figures of the cost of construction that have been considered in this comparison include the cost of sedimentation basins for the American system of filtration plant; but that they do not for the sand filtration plant.

The statement has sometimes been made in regard to the American system of filtration, that "the use of alum is injurious to the health." The writer has already discussed this objection quite fully, and it is hardly necessary for him to state that, in his opinion, there need not be any apprehension felt in regard to the use of alum or sulphate of alumina, if it is done in the manner which conforms to the latest experimental knowledge and practical experience.

In closing, the writer wishes particularly to emphasize the fact, that the opinions which he has expressed in this paper in regard to the comparative efficiency of American system of filtration plants which are in actual service, have been based upon the operation of first class plants that have been built in accordance with the most advanced knowledge (derived from late experimental research) that there is upon the subject. The writer also wishes to state that his opinions, as above mentioned, do not in any manner refer to the general run of "Mechanical Filters" which are in use in the United States or elsewhere.

AMERICAN STEEL RAILS FOR AUSTRALIA are being ordered in preference to those of English manufacture. A dispatch to the London "Times," from Melbourne, states that the government of New South Wales has found such difficulty in placing in England an order for 2,000 tons of steel rails of high carbon quality that it has been compelled to place the order in America, where the manufacturers have readily undertaken the contract at $25 per ton.

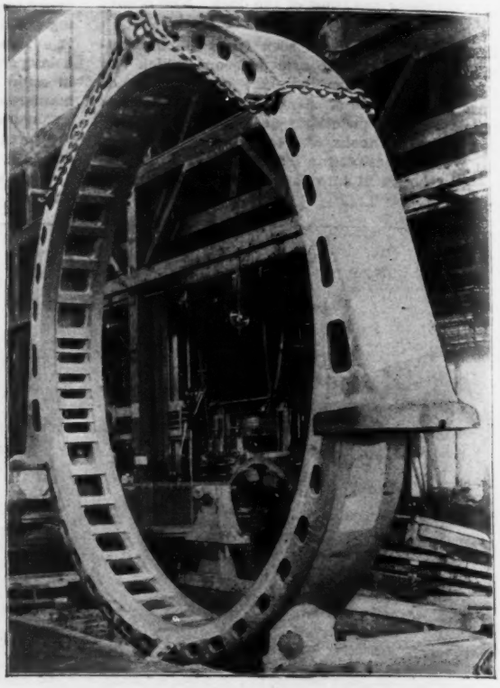
A LARGE THREE-PHASE GENERATOR FOR THE EDISON ELECTRIC ILLUMINATING CO., BROOKLYN, N. Y.

The illustration here given represents the armature ring of the great three-phase alternating current generator recently shipped from the Schenectady works of the General Electric Co., to the Edison Electric Illuminating Co., Brooklyn, N. Y. It will be installed in the new station at Bay Ridge, on the Long Island side of the Narrows, and will be used to supply high tension current to various substations distributed over the 75 sq. miles which the company proposes to furnish with electricity. At the substations static transformers will be employed to drop the pressure to 375 volts, at which pressure rotary converters will be operated to supply the present Edison three-wire low tension circuits.

Some idea of the size of this machine may be formed when it is stated that five flat cars were required to transport its various parts. In technical language the generator is rated as an A. P. 40-1,500-75, meaning that it is an alternating three-phase rotary field type, having 40 field poles and an output of 1,500 K-W. at a speed of 75 revolutions per minute. The armature coils or windings will be mounted inside of the large ring here shown. The construction and arrangement of these coils is a feature of recent General Electric large three-phase machines, admitting of the direct generation of very high elecromotive forces, thus doing away with the constant loss due to step-up transformation. Another advantage of this class of machinery is that the alternating current does not have to pass through any collecting rings or brushes, but passes out directly to the lines. The armature will be supported upon tracks and provided with a device for moving it along parallel with the shaft, so the field and armature coils can be examined or repaired. The field which revolves inside the stationary armature resembles a large fly-wheel. It consists of a massive cast-iron hub with eight spokes, to the ends of which is bolted a heavy steel ring. To the outside of this ring are bolted 40 pole pieces, built of sheet iron stampings or laminations. These poles are wound with a copper ribbon about 1-16 in. by 1½ ins. wound on edge. The 40 poles are connected in series and supplied with a low tension direct current by two copper rings mounted upon the driving shaft.

The field will be mounted directly upon the 27-in. shaft of a four cylinder triple expansion McIntosh & Seymour steam engine. On the same shaft will be a heavy fly-wheel intended to prevent variation in speed. The builders guarantee no greater variation than one-quarter of 1% per revolution, which will not cause any perceptible change in the brilliancy of lamps. While the generator is rated at 1,500 K-W., it is designed to carry safely 2,000 K-W. Some of the main dimensions of the machine are as follows:

Span of casting or lower half of armature frame	25 ft.
Vertical outside diameter of armature frame	31 ft. 2 ins.
Length along shaft	51 ins.
Weight of revolving field	59,000 lbs.
Total weight	163,000 "



ARMATURE FRAME FOR 2,000 K-W. THREE-PHASE GENERATOR FOR THE EDISON ELECTRIC ILLUMINATING CO., BROOKLYN, N. Y.
The General Electric Co., Schenectady, N. Y., Builders.

BOOK REVIEWS.

ALASKA.—Handbook No 86. Bureau of the American Republics, Washington, D. C. Director, Joseph P. Smith. Paper, 8vo.; pp. 133; folding map.

This pamphlet has also been issued in consequence of the great demand for fresh and reliable information about Alaska due to the recent discoveries of gold in the Klondike region. The Territory has an area of 577,390 sq. miles, with a seacoast of 26,000 miles, and the population by the census of 1890 was 32,052, of which only 1,298 were white, the rest being Indians, Mongolians and mixed blood. One of the characteristics of the country is the network of rivers and lakes, that serve as the most available means of transportation. The temperature varies from — 47° to + 60 and 70°, but the winter lasts from September to May. In June the sun rises at about 1.30 a. m. and sets at 10.30 p. m., while in winter it rises about 10 a. m. and sets about 2 or 3 p. m., rising only a few degrees above the horizon. Mosquitoes and black flies are so numerous and vicious in warm weather as to cause misery almost beyond belief. Most readers will give particular attention to Chapter 9, "Mineral Resources; The Klondike Gold Region," which opens by the statement that gold, silver, copper, lead, iron, coal and platinum are found. The low-grade ore of the celebrated Treadwell gold mines yields $3.20 per ton, and the supply seems inexhaustable. Several papers are devoted to the U. S. mining laws and regulations. The usefulness of the map has been much injured by reducing it to too small a scale.

MODERN LOCOMOTIVES: Illustrations, Specifications and Details of Typical American and European Steam and Electric Locomotives. By David Leonard Barnes. New York: "The Railroad Gazette;" large 4to cloth; pp. 405, with 575 illustrations. $7.00.

In 1883 and again in 1886 "The Railroad Gazette" reprinted in a large quarto volume the illustrations of locomotives which had appeared in its pages for some time past under the title "Recent Locomotives." The present volume is similar in form to its predecessors; but differs from them in its material so considerably as to deserve the change of title. While nearly all the space is devoted to the drawings and engravings, the book opens with several excellent papers on various features of locomotive design, including "Recent Improvements in Locomotives," "Counterbalancing," "Locomotive Tests," "Locomotive Testing Plants" and "Experiments with Exhaust Apparatus."

There is also an interesting table which gives the particulars of "fast and unusual runs," beginning with one on the Pennsylvania from Philadelphia to Jersey City in 1880, and ending with the run from Chicago to Denver on the Chicago, Burlington & Quincy, Feb. 15, 1897.

The illustrations in this volume have in most cases been furnished especially for it by railway companies or locomotive building concerns. All the drawings for the volume were selected by the late D. L. Barnes, and after his death the editorial supervision of the work was carried on by his assistant, Mr. J. C. Whitridge.

Separate sections of the book are devoted to foreign locomotives and electric locomotives, but are naturally much less complete than the other, owing to the greater difficulty of obtaining data.

The most useful part of the work is unquestionably the pages from 280 to 323, which are devoted to miscellaneous details. It is to be regretted that more space was not given to this department, even at the sacrifice of some of the full-page elevations and perspective views of locomotives.

The ideal treatise for the locomotive designer's use would unquestionably be made up almost wholly of detail drawings, and these would be grouped as are the drawings on a locomotive works drafting room, all the drawings of one sort together. But the difficulties in the way of compiling such a work are likely to prove insurmountable. It is easier to plan an ideal work than to carry it out.

The volume before us is one which every one interested in practical locomotive design will certainly wish to possess, and it reflects much credit on those responsible for its appearance.